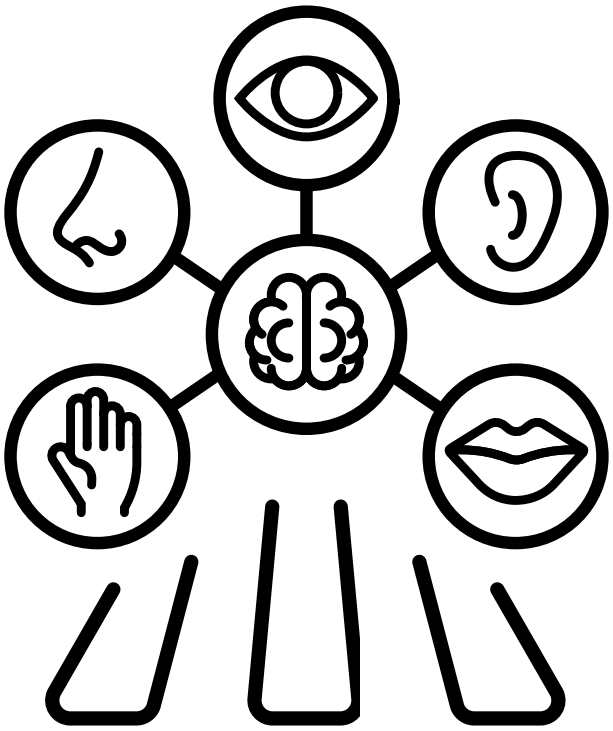
IMRF

INTERNATIONAL
MULTISENSORY
RESEARCH
FORUM

BRUSSELS 2023



UCLouvain

27-30 June 2023
Blvd Auguste Reyers
80, 1030 Brussels

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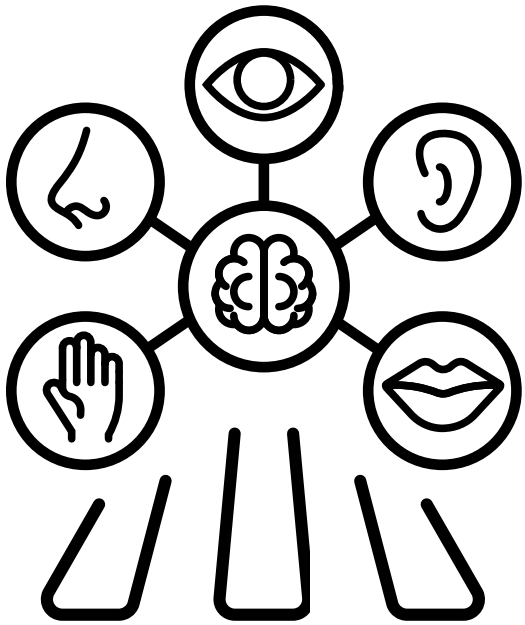

SCHEDULE OF EVENTS
June 27

	ROOM
12:00-1:45pm: Registration desk	BLUEPOINT ENTRANCE
1:45-2pm: Opening remarks - *Olivier Collignon*	EINSTEIN
2-3:30pm: Symposium 1 Where, when and how? Targeting the neural mechanisms and cortical network dynamics underlying multisensory perception *Daniel Senkowski*, Uta Noppeney, Virginie Van Wassenhove, Tim Rohe, Salvador Soto-Faraco*	EINSTEIN
3:30-4pm: Coffee break	HALL
4-5:30pm: Talk session #1 [Chair: E. Striem-Amit] Brain adaptation to sensory deprivation	EINSTEIN
5:30-5:45pm: Break	HALL
5:45-7pm: Keynote lecture Homo Cyberneticus: Neurocognitive embodiment of artificial limbs - *Tamar Makin*	EINSTEIN
7-10pm: Welcome reception and poster session #1	GARDEN + TENT

June 28

8-8:30am: Welcome coffee (Hall) — HALL

8:30-10am: Talk session #2 [Chair: M. Gori] — EINSTEIN
Multisensory development in humans and other animals

10-10:30am: Coffee break — HALL

10:30-12pm: Symposia 2

- Multisensory interactions in three-dimensional peri- and extrapersonal space - *Durk Talsma*, Nathan Van Der Stoep, Mark Wallace, Tommaso Bertoni* — EINSTEIN
- The multisensory nose : How odors interact with the other senses in humans - *Arnaud Leleu*, Jasper de Groot, Jessica Freiherr, Putu Khorisantono, Janina Seubert* — NEWTON

12-2pm: Lunch and poster session #2 — GARDEN + TENT

2-2:30pm: Symposium 3 — EINSTEIN
How does multisensory computation vary across the sensory hierarchy?
Amit Khandhadia, Rebecca Norris*, Jennifer Bizley*, Andrea Hasenstaub, Celine Cappe, Phillip Coen, Tim Rohe*

3:30-4pm: Coffee break — HALL

June 28

4-5:30pm: Symposia 4

- How spontaneous activity and sensory experience sculpt multisensory connectivity in cortical and subcortical brain regions? *Christiaan Levelt*, Huub Terra, Marta Nieto, Teresa Guillamon Vivancos, Leopoldo Petreanu* — EINSTEIN
- Multisensory processing in face-to-face communication *Stefania Benetti*, Ambra Ferrari*, Davide Bottari, Hans Rutger Bosker, Jamie A. Ward, Judith Holler* — NEWTON

5:30-5:45pm: Break — HALL

5:45-7pm: Keynote lecture — EINSTEIN

Visual perception – and how to restore it when the eyes fail - *Pieter Roelfsema*

June 29

8-8:30am: Welcome coffee — HALL

8:30-10am: Talk session #3 [Chair: M.M. Murray] — EINSTEIN
Audiovisual and visuotactile multisensory integration

10-10:30am: Coffee break — HALL

10:30-12am: Symposia 5

- Naturalistic movies and novel resting-state approaches; non-classical methods in plasticity research. — EINSTEIN
  Marcin Szwed, Sam Nastase, Maria Zimmermann, Giacomo Handjaras, Daniel Margulies, Velia Cardin, Katarzyna Ciesla*

- *Recent advances in multisensory research methods* — NEWTON
  Meike Scheller, Peter Scarfe, Nick Prins, Rebecca Hirst, Micah M. Murray, Ioannis Delis*

12-2pm: Lunch and poster session #3 — GARDEN + TENT

2-3:30pm: Symposium 6 — EINSTEIN
Post-natal transient blindness : how does the visual system cope with it ?
Stefania Mattioni, Ehud Zohary, Marc Ernst, Rashi Pant*

June 29

3:30-4pm: Coffee break — HALL

4-5:30pm: Symposia 7

- The intimate interplay of movement and touch
  Matej Hoffmann, Luke Miller, Lucile Dupin, Konstantina Kilteni, Tobias Heed* — EINSTEIN

- *The development of audiotactile and visuotactile integration for human body representations from infancy to adolescence.*
  Maria Bianca Amadeo, Monica Gori*, Andrew J. Bremner, Dorothy Cowie, Meike Scheller* — NEWTON

5:30-5:45pm: Break — HALL

5:45-7pm: Keynote lecture
John J. Foxe — EINSTEIN

8pm: Social dinner — LA CHAUFFERIE

June 30

8-8:30am: Welcome coffee (Hall) — HALL

8:30-10am: Talk session #4 [Chair: M. Wallace] — EINSTEIN
Impact of sensory experience on body and emotion representation

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10-10:30am: Coffee break (Hall) — HALL

10:30-12am: Symposium 8 — EINSTEIN
Resolving old debates, posing new questions: Factors influencing the development of multisensory processes in typical and atypical populations
Paul Matusz, Mark Wallace, Milene Bonte, Marko Nardini*

12-1pm: Closing and business meeting — EINSTEIN

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BLUEPOINT
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The IMRF2023 meeting is hosted at BluePoint Bruxelles (Boulevard Auguste Reyers 80 - 1030 Bruxelles).

Bus and tram stop : Diamant or Meiser.

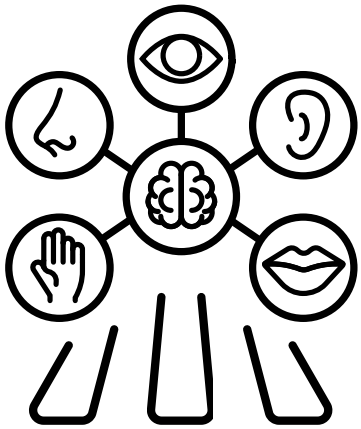
BluePoint is a trade fair venue situated 30 mins away in public transportation from the magnificent "Grand place" of Brussels. It is easily accessible from the city center or from the airport, by public transportation (bus, tram) or by car - see detailed access plan here.

2023 KEYNOTE
TAMAR MAKIN

University of Cambridge

Homo Cyberneticus: Neurocognitive embodiment of artificial limbs

(When) should we all get artificial limbs? Technology is progressing at a remarkable pace, providing us with wearable robotic technologies to substitute, and even supplement, our own limbs, freeing humans from the biological constraints of their own bodies. But can the human brain embody these exciting technologies as new body parts? I will describe recent neuroimaging and behavioural studies we've been conducting in amputees who use prosthetic limbs to substitute their missing hand function. These studies provide a first glimpse into neurocognitive opportunities and limitations towards artificial limb embodiment. I will then present ongoing studies examining what happens to the somatosensory and motor systems of able-bodied people using the Third Thumb (by Dani Clode Design) – a hand augmentation device. Collectively, these studies suggest that although, in principle, opportunities exist for harnessing hand neural and cognitive resources to control artificial limbs, the brain does not assimilate neural representations for the artificial limb with those for the biological body, creating opportunities for nonbiomimetic technological interfaces.



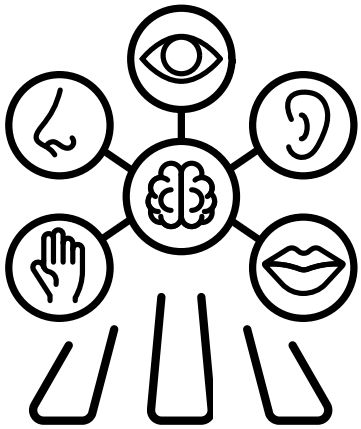
2023 KEYNOTE
PIETER ROELFSEMA

Netherlands Institute of Neuroscience

Visual perception – and how to restore it when the eyes fail

A long-standing dream of scientists is to be able to directly project images from the outside world onto the visual brain, bypassing the eyes. This method could provide a solution for blind and visually impaired patients. It is the only possible solution for patients in whom the connection between eye and brain is lost so that a prosthesis in the eye is not an option.

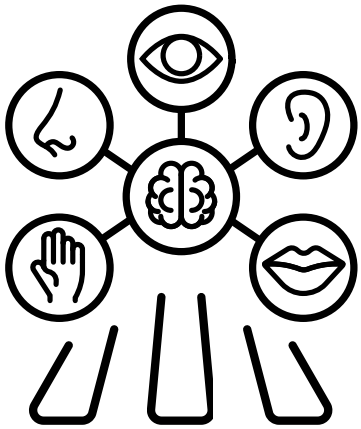
I will first give an overview of the functioning of the visual cortex, which has low level areas for the analysis of simple visual features and higher areas for the analysis for more complex properties such as object category and face recognition. I will then discuss the mechanisms that determine whether a visual stimulus will reach consciousness or not. It is well established that the electrical stimulation of electrodes in the visual brain leads to artificial percepts called "phosphenes". This method also works in patients who have been blind for decades. The goal of our own research is to bring a prosthesis for the visual brain closer. We implanted 1000 electrodes in the visual cortex to generate complex visual patterns. We demonstrated that this stimulation leads to interpretable images, in the same way that pixels form recognizable patterns on a screen. These new neurotechnological developments take important steps in the direction of prostheses that can restore a rudimentary form of vision.



2023 KEYNOTE
JOHN J. FOXE

University of Rochester

To be announced



SYMPOSIUM #1
JUNE 27 | 2-3.30 PM
EINSTEIN ROOM

Where, when and how? Targeting the neural mechanisms and cortical network dynamics underlying multisensory perception

Daniel Senkowski*, Uta Noppeney, Virginie Van Wassenhove, Tim Rohe, Salvador Soto-Faraco

***Main organiser**

Neuroimaging studies in the last decades have provided compelling evidence that multisensory interactions can occur in virtually all areas of the brain. More recently, studies have extended this question by asking not only where in the brain multisensory interactions occur, but also when and how. In this proposal, we will present recent electrophysiological and functional neuroimaging studies that have explicitly addressed this question by using advanced computational modelling approaches to combine psychophysical and neuroimaging data in multisensory paradigms (talks by Uta Noppeney; Virgine van Wassenhove; Tim Rohe).

Our understanding of the spatio-temporal network dynamics underlying multisensory communication has already improved with these innovative analysis approaches. Specifically, the data presented in this symposium provide evidence suggesting that the perception of multisensory objects is shaped by hierarchically organized cascades of neural computations that, in turn, rely on the dynamic interplay of lower and higher cortical areas. In addition, we hypothesize that ongoing and stimulus-driven neural oscillations in different frequency bands, and thus with different temporal resolutions, play a central role in initiating and sustaining multisensory processes (talks by Salvador Soto-Faraco and Daniel Senkowski). Collectively, this symposium will provide a state-of-the-art overview on research addressing how cortical network dynamics shape multisensory perception.

Talk 1 - Attentional control of multisensory causal inference and perception

Uta Noppeney 1
1 Donders Institute for Brain

To form a coherent percept the brain needs to solve the causal inference or binding problem deciding whether signals come from common sources and should hence be integrated or else be segregated. First, I discuss our recent research at the behavioral, computational, and neural systems level that investigates how the brain solves the causal inference problem. Next, I will show that attention can influence causal inference via two distinct computational mechanisms in early sensory (V1-3) and later audiovisual (PT, IPS) cortices.

Talk 2 - Temporal comodulation in multisensory causal inference

Virginie van Wassenhove 1
1 INSERM Cognitive Neuroimaging Unit

Perception relies on inferences about the causal structure of the world provided by multiple sensory inputs. In ecological settings, multisensory events that cohere in time and space benefit inferential processes, e.g. hearing and seeing a speaker enhances speech comprehension. Using psychophysics and functional connectivity characterization of human brain activity measured with magnetoencephalography (MEG), I will discuss how temporal comodulation may contribute to the analysis and synthesis of incoming speech and non-speech signals.

Talk 3 - The role of alpha oscillations for causal inference in multisensory perception

Tim Rohe 1
1 Friedrich-Alexander-University of Erlangen-Nürnberg

Humans integrate signals across the sensory modalities to obtain a multisensory perception of their environment if they infer that the signals arose from a common cause, but they segregate signals from independent causes. To infer the causal structure of multisensory signals, humans combine causal evidence from the signals' spatiotemporal relations with a priori causal assumptions (i.e., a causal prior). On the one hand, the causal prior adapts to the multisensory statistical regularities of the recent stimulus history. On the other hand, the causal prior may also capture at a computational level that the neural communication between (multi-) sensory regions fluctuates intrinsically as indicated by neural oscillations. Thus, the brain's tendendy to integrate or segregate incoming multisensory signals (i.e., the causal prior) may depend on the brain's a priori oscillatory state. A recent study showed that the causal prior was indeed correlated with the power and phase of prestimulus alpha oscillations. In this talk, I will present EEG and psychophysical studies that investigate wether prestimulus alpha-phase has a causal effect on the causal prior by manipulating alpha phase using visual entrainment. Our results support the notion that alpha phase indicates a transient prestimulus time-window for optimal multisensory interactions between sensory and/or higher association regions as captured by a causal prior at the computational level.

Talk 4 - The role of conflict in multisensory perception

Salvador Soto-Faraco 1

1 Universitat Pompeu Fabra

Multisensory perception is often studied through the consequences of inter-sensory conflict in illusions, such as the McGurk effect, ventriloquism, and the rubber hand. Moreover, Bayesian accounts of cue fusion and causal inference also draw on inter- sensory conflict to measure and to model the outcomes of multisensory integration. Given the prevalence of conflict in this field of research, it is remarkable that accounts of multisensory perception have paid little attention to the cognitive processes of conflict monitoring and resolution. Here, we present EEG and fMRI data showing that audio- visual conflict in speech triggers neural mechanisms of conflict processing in fronto- medial brain areas. Additional experiments measuring behavioural and EEG in a cross- modal spatial perception protocol support the hypothesis that frontal conflict mechanisms are involved, more generally, during multisensory perception. Collectively, these results are indicative of the putative interplay between higher level control mechanisms and lower-level perceptual processes. In particular, we suggest that the role of conflict detection and resolution mechanisms would be the regulation of competition between alternative perceptual representations during causal inference.

Talk 5 - Multisensory perception utilizes neural oscillations: Evidence from EEG and EcOG recordings

Daniel Senkowski 1

1 Universitätsmedizin Berlin

The processing of multisensory information in our environment relies on the rapid integration and segregation of stimuli from different sensory modalities. In particular, stimuli enter our sensory systems with different temporal and spatial properties, and thus highly adaptable and flexible neural mechanisms are required for the vast amount of multisensory processing that our brains seem to perform effortlessly in everyday life. In this talk I will present evidence from EEG and EcOG studies in human participants that ongoing and stimulus-driven neural oscillations, in particular power modulation, phase resetting/locking and functional coupling, may provide important neural mechanisms underlying multisensory integration. Specifically, the different frequency bands of neural oscillations, with their different temporal resolutions and functions, appear to be well suited for integrating and segregating stimuli with different temporal and spatial properties across sensory modalities.

SYMPOSIUM #2.A
JUNE 28 | 10.30-12PM
EINSTEIN ROOM

Multisensory interactions in three-dimensional peri- and extrapersonal space

Durk Talsma*, Nathan Van Der Stoep, Mark Wallace, Tommaso Bertoni

***Main organiser**

Peripersonal space (PPS) is the region of space immediately surrounding the body: a flexible region that is loosely defined as the region that we can reach and where we can manipulate our environment. PPS is represented by a dedicated network of multisensory neurons with visual, auditory, and tactile receptive fields. It is currently still unknown how PPS is represented in the brain, how the respective senses contribute to representing the PPS, and how the receptive fields of the contributing neural circuits contribute to establishing a stable representation of the PPS. Furthermore, defining PPS immediately makes clear that there is a space outside PPS, often labeled extra personal space (EPS).
It follows that the establishment of PPS and EPS is strongly dependent on depth perception. Until recently, however, multisensory research has largely omitted depth as a crucial focus of investigation, resulting in depth being identified as the forgotten dimension in multisensory research. Here we aim to discuss recent studies investigating how the senses interact in different regions of space and bring together state of the art contributions from the cognitive neurosciences, behavioral methods, computational modeling, and virtual reality (VR).
Noel and Wallace will discuss how the PPS can be established on the basis of keeping track of the environment using a Bayesian inference mechanism. Tommaso will present a computational model that can predict tactile stimulation from proprioceptive and visual stimuli. He demonstrates how reference frame transformations are used to bring hand-centered coordinates in line with a visual reference frame. Van der Stoep will present behavioral data showing how audiovisual integration decreases as a function of distance to the observer, specifically for distances of 10 meters or more by measuring the McGurk effect. Finally, Talsma will focus on the use of virtual reality as an effective paradigm for investigating multisensory interactions in 3D space. In addition to focusing on the methodological challenges of using VR, he will also present electrophysiological and behavioral results from a VR study.

Talk 1 - Peri-personal space as a Bayesian prior and window into canonical neural function

Jean-Paul Noel 1, Mark T. Wallace 2
1 New York University, 2 Vanderbilt University

Peri-personal space (PPS) represents the interface between the body and environment, guiding avoidance and approaching behaviors. Here we attempt to integrate recent psychophysical, neurophysiological, and computational evidence regarding PPS to move beyond the established functional description, and to place PPS within a broader neural and computational framework. a
PPS remaps as a function of numerous stimulus and contextual features. Recently we have shown psychophysical and electroencephalography (EEG) evidence that PPS is subject to serial dependencies on extremely rapid time-scales, suggesting that PPS encoding keeps track of statistical regularities of the environment, much like Bayesian priors. More directly, we had subjects perform a visuo-proprioceptive estimation task in virtual reality where the body disappeared. Findings suggest that proprioceptive estimates are 'pulled' toward visual objects, and modeling of these results requires a prior for visuo- proprioceptive coupling and cannot be accounted for by simple maximum likelihood estimation. Lastly, we mapped PPS and recorded EEG in neurotypical and autistic subjects in non-social and social contexts. Results demonstrate that while PPS shrinks during socials context in neurotypical individuals, its boundary becomes sharper in autistics. Computationally, changes in the PPS gradient can be accounted for by divisive normalization, which is speculated to be altered in autism. Collectively, we argue that PPS is a prior for coupling exteroceptive signals (e.g., audio, vision) with senses on or in the body (e.g., touch, proprioception). Casting PPS within a Bayesian framework allows making novel predictions and, more importantly, renders its study central to the study of brain function.

Talk 2 - A neural network model learning peripersonal space representation from ecological multisensory stimulation

Tommaso Bertoni 1, Elisa Magosso 2, Andrea Serino 1
1 University of Lausanne, 2 University of Bologna

Peripersonal space (PPS) is represented by a dedicated network of multisensory neurons with visual (or auditory) receptive fields anchored to specific body parts, and tactile receptive fields covering the same body parts. This requires reference frame transformations across different sensory representations of space. PPS is therefore thought to subtend the multisensory representation of the body in space. PPS representations are thus unlikely to be hard-wired, but may emerge during development from natural stimulation, based on the relations between visual, proprioceptive, and tactile inputs. Still, we have a limited understanding of the underlying neural processes involved. Here, we model how reference frame transformations and PPS representation may emerge from ecological stimulation in a biologically plausible neural network. Our network consists in a proprioceptive population (coding for hand position), a visual population (coding for external stimuli position) and a tactile population (coding for touch on the hand), converging towards a multisensory population. The network's connectivity is self- tuned based on a Hebbian mechanism designed to learn the statistical regularities in multisensory inputs.
The network learned to predict tactile stimulation from proprioceptive and visual stimuli, thus performing the aforementioned reference frame transformations. We reproduced our main findings in extended, but conceptually identical networks, learning the statistical regularities in more complex and realistic inputs. We thus propose that PPS representation and reference frame transformations may emerge through a unified neurocomputational process: the integration of multisensory information consistently with a model of the body in the environment, learned from the natural statistics of sensory inputs.

Talk 3 - The limits of audiovisual speech integration in 3D space

Nathan Van der Stoep 1

1 Utrecht University

Integrating the voice and the lips of a speaker can aid audiovisual speech perception. In daily life we talk to people from various distance, ranging from close to far away, depending on the situation. As the distance between the speaker and the listener increases, various properties of the visual and auditory components of audiovisual speech alter. For example, the retinal image size, auditory intensity, and timing between sensory inputs can change with distance. In the present study, we investigated how audiovisual speech integration, lip reading, and auditory speech comprehension changes as a function of distance from 1 m to 20 m using auditory, visual, audiovisual, and McGurk effect stimuli with faces of an average size and voice intensity. The influence of distance on stimulus properties like retinal image size and auditory intensity were also simulated while keeping a fixed distance between the stimuli and the observer. We observed a reduction in the McGurk effect with increasing distance starting around 10 m distance. We also observed a (stronger) reduction in the McGurk effect for the simulated distances starting from the retinal image size and intensity associated with the 10 m distance. Lip reading performance decreased with increasing distance, but auditory comprehension did not. Overall, these results indicate that audiovisual speech integration is likely most beneficial when talking to people within 10 m distance. After 10 m, visual lip movement cues deteriorate and their influence on auditory comprehension declines.

Talk 4 - Audiovisual interactions in virtual peripersonal and extrapersonal space

Durk Talsma 1, Jonas De Bruyne 1, Klaas Bonbeke 1, Wouter Durnez 1, Glenn Van Wallendael 1

1 Ghent University

Determining the distance of an object in our external world is a hallmark of our perceptual systems, as it allows us to successfully navigate through our environment and manipulate objects in it. Interestingly, it has been established that there a distinction between peripersonal space and extrapersonal space, with the former being defined as the volume surrounding our body that we can reach, and the latter as the area surrounding the peripersonal space. Although some studies have suggested that multisensory interactions differ between the peripersonal and extrapersonal space, relatively little is still known about the impact of distance on multisensory perceptions. Here we aim to address this gap in the literature by using a state-of-the-art virtual reality setup and an experiment that is based on a classic study by Giard and Peronnet (1999, J. Cog. Neuroscience). In VR, a sphere was presented at a simulated distance of either 70 cm or two meters, that could temporarily deform into either a vertical ellipsoid or a horizontal on. These deformations could be accompanied by a low or a high-pitched tone. In addition, these tones could be presented with and without deformation of the sphere. Horizontal deformations and low- pitched sounds were designated as object A and vertical/high-pitched tones as object B. Participants were instructed to make a speeded response to discriminate between these two objects. Results showed a response time advantage of audiovisual objects compared to either auditory-only or visual-only objects. These results were found for both near and far stimuli.

SYMPOSIUM #2.B
JUNE 28 | 10.30-12 AM
NEWTON ROOM

The multisensory nose : How odors interact with the other senses in humans

Arnaud Leleu*, Jasper de Groot, Jessica Freiherr, Putu Khorisantono, Janina Seubert

***Main organiser**

From the very beginning of life, human beings are exposed to a complex multisensory environment. To navigate this rich source of information coming from all the senses at the same time, humans must integrate multisensory inputs to form coherent percepts. In this concert of the senses, some modalities are generally deemed “major”, such as vision and audition, whereas olfaction, which has long been considered poorly functional in humans, is deemed “minor”. However, in the last decades, a surge in research has revealed how odors are an integral part of our perception and participate in high-level human cognition. In that respect, the proposed symposium aims to provide recent insights on how the sense of smell communicates to, and integrates with, the other senses for a unified perception of the environment in humans. The four speakers will offer an overview of this emerging topic by drawing upon research conducted in human infants and adults using diverse behavioral and neuroimaging techniques. In particular, they will demonstrate how odor inputs foster the perception of two highly relevant objects for our species: conspecifics and food. This symposium will thus shed important light on the unsuspected role of the sense of smell in our perception of the environment, and underline how humans utilize chemosensory information to make sense of their surroundings. More generally, it will open perspectives to further investigate the fascinating role of olfaction in a variety of multisensory contexts.

Talk 1 - Tips from the nose: Odor-driven face categorization in the infant brain

Arnaud Leleu 1
1 Utrecht University

While human vision is poor at birth and follows a protracted development over the first year of life, infants must rapidly acquire the ability to categorize a variety of visual stimuli as faces to engage in social interaction. Does olfaction, an early-maturing sense and primary medium of social communication, drive the development of face categorization in the infant brain? In this talk, I will address this issue through a series of experiments using scalp electroencephalography (EEG) and a frequency-tagging approach. I will demonstrate that one of the most relevant social odors for young infants, the mother's body odor, shapes face categorization in the developing brain. I will show that maternal odor enhances face- selective neural activity over the right occipital cortex at 4 months, this effect being absent for non-face objects, except for objects that can be categorized as faces (eliciting face pareidolia in adults). I will also illustrate how the facilitating effect of maternal odor gradually declines between 4 and 12 months as face categorization becomes more efficient by itself. Finally, I will reveal that the odor effect fades in the 4-month-old brain when face categorization is made less demanding for the visual system. Altogether, these findings will disclose how the infant brain builds upon the first odor learned during mother-infant interactions to apprehend the social environment in the less mature sense of vision.

Talk 2 - There's something in the air: How human smells influence emotional face perception and relate to relationship quality

Jasper H.B. de Groot 1
1 Radboud University

The millennia-old myth that smells are unimportant to us is gradually evaporating. Empirical studies have showcased excellent smell skills we humans share with other animals: assessing the nutritional value of food, avoiding hazardous substances, and even social communication. The question "(how) do human smells affect our social lives?" was listed in Science's 125 most important queries of this century, and still, this multidisciplinary question has not been answered. Combining psychological experiments with chemical analysis techniques, I intend to get a deeper insight into how human chemical communication works, in particular the adaptive human capacity to produce and perceive the smell of fear. To grasp its potential importance in everyday life where senses like vision are considered dominant, I additionally test (in two separate experiments) how smells like human fear odors interact with visual information that is congruent, conflicting, or ambiguous, employing a well-validated face morph paradigm. What I find is that fear smell exerts its strongest effects when visual information (faces morphed between expressions of fear and disgust) is most ambiguous. In another line of research, I investigate the importance of smell in the domain of romantic relationships. In two studies, we find that one of the best predictors or relationship satisfaction is the evaluation of the partner's smell; this effect was stronger than evaluations of looks and voice. Taken together, smells affect interpersonal communication, complementing and sometimes even trumping other modalities.

Talk 3 - Perception and processing of multisensory food stimuli

Jessica Freiherr 1,2
1 Universität Erlangen-Nürnberg, 2 Fraunhofer Institute for Process Engineering and Packaging IVV

During everyday consumption of food, all our five senses come into play and efficiently provide us with a holistic percept. Especially the chemical senses render important during the perception of food. Within my talk, I will specifically focus on the interaction of the olfactory with the visual system during food consumption. Therefore, I will use a bottom-up approach and will first provide insights on cognitive processing of smells based on a recent meta-analysis of experiments involving olfactory stimulation. Here we provide knowledge about the cortical network involved in odor processing in general and in food-odor processing specifically. I will then give an overview of our results on olfactory-visual integration processing during food perception based on behavioral as well as functional MR imaging (fMRI) approaches. Further, I will present a sequence of studies involving cognitive load effects on odor, taste and combined odor-taste perception in lean and obese participants. The presented research contributes to a deeper understanding of the multisensory interaction and integration processes during food perception and consumption in the healthy and obese human.

Talk 4 - Flavour as a multisensory percept: Cortical and cognitive representations of odour-taste concordance

Putu A. Khorisantono 1, Janina Seubert 1
1 Karolinska Institutet

Food consumption is an inherently multisensory experience: olfaction, gustation and somatosensation are merged in the oral cavity, forming bound percepts which are experienced holistically as the food's flavour. Eliciting strong hedonic responses, these integrated flavour percepts form an object representation which plays a key role in guiding us towards nutritious foods and protecting us from accidental poisoning. How the conceptual overlap between the different modalities is cognitively represented and cortically encoded into a flavour object, however, remains poorly understood. In this talk, we will give an overview of the cortical networks responsive to olfactory-gustatory overlap and demonstrate that the representation of odour-taste associations into a flavour object follows a flexible representation of concordance overlap that is directly related to pleasantness. The adaptive value of such flexible representations is discussed with respect to potential benefits balancing tolerance to natural variability in odour composition against the need for contamination avoidance. We will end the talk by giving an outlook on how exogenous and endogenous influences, such as metabolic state, interact with graded representations of flavour object identity to induce changes in reward value, and a discussion of the implications of these findings for an improved understanding of appetite regulation.

SYMPOSIUM #3
JUNE 28 | 2-3.30 PM
EINSTEIN ROOM

How does multisensory computation vary across the sensory hierarchy?

Amit Khandhadia*, Rebecca Norris*, Jennifer Bizley*, Andrea Hasenstaub, Celine Cappe, Phillip Coen, Tim Rohe

***Main organisers**

Sensory systems in the mammalian brain transduce stimuli received by independent sensory epithelia into usable information that underlies our perception of the world. Sensory information flows through subcortical structures to sensory cortices to higher sensory and non-sensory brain regions that ultimately guide behaviour. While each sensory system has its own dedicated processing pathway, signals from multiple senses converge at all levels of the sensory hierarchy offering the potential for multisensory integration at various levels of processing. In this symposium, we will explore the similarities and differences of the computations of different regions at various levels of sensory systems.

Beginning with primary sensory cortex, Dr. Andrea Hasenstaub will explore how visual information influences primary auditory cortex in the mouse. Dr. Celine Cappe will outline the pulvinar, in the thalamus, as a multisensory hub, describing how distinct frequencies of the local field potential allow multiplexing of unisensory and multisensory information. Moving to higher-order sensory cortex, Amit Khandhadia will discuss how a visually face-selective region of the macaque cortex integrates auditory and eye position signals across space. To examine the difference between early cortical areas and later multisensory association areas in shaping performance in multisensory behaviours, Dr. Pip Coen will describe optogenetic and electrophysiology experiments that compare the roles of frontal motor cortex and primary sensory areas in multisensory behaviors. Finally, Dr. Tim Rohe will present work comparing the roles of early sensory cortex and parietal cortex in causal inference showing that spatial disparity and temporal correlation each have distinct spatio-temporal profiles during audiovisual spatial task performance.

We have drawn together a diverse set of speakers whose work spans multiple species and involves numerous areas of multisensory processing. This symposium would provide a unique perspective to multisensory processing that would be of wide interest to the attendees of IMRF.

Talk 1 - Visual and contextual influences on processing in the awake mouse auditory cortex

Dr. Andrea Hasenstaub 1

1 University of California San Francisco

Recent studies have established significant anatomical and functional connections between visual areas and primary auditory cortex. These crossmodal interactions may be important for cognitive processes such as communication and spatial perception and have been observed in both animals and humans. We have found that in awake mouse auditory cortex, visual influences on neural function are surprisingly strong and widespread. In this talk, we will explore what visual signals are represented in the auditory cortex, how they reach the auditory cortex, how they influence processing of auditory information, and the consequences for neural processing and ultimately, behavior.

Talk 2 - What about the thalamus? The role of the medial pulvinar in multisensory integration

Dr. Celine Cappe 1

1 Centre de Recherche Cerveau et Cognition

Multisensory integration has been shown to take place at different cortical stage. The thalamus and in particular the pulvinar could also play a major role in such processing. The medial pulvinar is densely connected with the cortex, specifically with the primary visual, auditory and somatosensory cortices, as well as with the multisensory parietal, temporal and prefrontal associative cortices and the premotor cortex. Based on its anatomical connectivity, the medial pulvinar is proposed to play an important role in the integration of information from multiple sensory modalities. However, its contribution to multisensory integration has rarely been directly investigated. To fill this knowledge gap, two macaque monkeys were trained on a fixation task, during which auditory, visual and audiovisual stimuli were presented. Single-units revealed the presence of visual, auditory and audiovisual neurons. Audiovisual neurons accounted for almost half of the neurons. Multisensory integration was mainly sub-additive and suppressive. Local field potentials were analyzed in the time domain and in four functional frequency bands. The frequency analysis showed a distinction between low and high frequencies. The two low frequency bands (4.5-8.5 Hz and 8.5-20 Hz) were strongly multisensory and very similar. On the contrary, high frequencies (35-60 and 60-120 Hz), were distributed between unisensory and multisensory responses. These results suggest the existence of a frequency coding for multisensory information. In conclusion, our study shows that the medial pulvinar is indeed a multisensory hub, multiplexing visual, auditory, and audiovisual information, which are characterized by different frequency rhythms.

Talk 3 - Audiovisual Integration of Social Information Across Space in Macaque Anterior Fundus Face Patch

Amit P. Khandhadia 1, Aidan P. Murphy 2, Lizabeth Romanski 3, Jennifer Bizley 1, David Leopold 2

1 University College London, 2 National Institute of Mental Health, 3 University of Rochester

Sensory systems of the mammalian cortex are often separated into primary sensory areas and secondary areas, which often contain specialization for specific high-level features. However, secondary areas often also receive multisensory information from numerous primary regions or other multisensory regions. One of these secondary areas in the macaque, the superior temporal sulcus contains several face patches, regions which respond more to faces than to non-face objects. However, this region also has extensive connections with auditory regions and multisensory spatial regions of parietal cortex, both of which were little explored. We recorded from the anterior fundus (AF) face patch in two macaque monkeys during presentation of audiovisual movies of macaque vocalizations. Many AF neurons were modulated by auditory vocalizations, both as an enhancement or suppression of the visual response. Interestingly, this auditory modulation did not depend on precise acoustic information as matching noise yielded similar audiovisual responses. To further examine the how spatial properties could affect this audiovisual modulation, audiovisual movies were presented within a virtual reality dome with the auditory and visual components spatially separated in multiple directions. Under these conditions, neural responses depended most prominently on eye position. Within multisensory responses, auditory modulation of visual responses tended to arise during later time windows and sound source position influenced the presence and size of audiovisual interactions but the effects across the population were heterogenous. Together, these results indicate that AF face patch neurons incorporate auditory signals into their spiking responses and different spatial properties can affect this modulation.

Talk 4 - Frontal cortex learns to add evidence across modalities

Phillip Coen 1

1 University College London

To make accurate perceptual decisions, the brain must combine information across sensory modalities. Probability theory suggests that evidence from independent cues should be combined additively, but it is unclear whether mice do this. We now show that mice combine auditory and visual spatial cues additively to localize a stimulus, a computation supported by unisensory processing in auditory and visual cortex and additive multisensory integration in frontal cortex. We developed an audiovisual localization task where mice turn a wheel to indicate the joint position of an image and a sound. While mice performed this task, with optogenetically inactivated different spots across cortex. We then recorded from >10,000 neurons in the frontal cortex during behaviour. In this task, mice integrated auditory and visual cues independently. An additive model predicted the mean response of mice to all cue combinations. Optogenetic inactivation experiments demonstrated that auditory and visual areas contribute unisensory information, whereas frontal cortex (secondary motor area, MOs) contributes multisensory information to the mouse's decision. Of the frontal areas recorded, only MOs activity could predict the mouse's upcoming choice. Consistent with the behaviour, neural activity in MOs reflected an additive combination of visual and auditory signals. Furthermore, an accumulator model applied to the sensory representations in MOs reproduced behaviourally observed choices and reaction times. We are now extending these methods to subcortical brain regions. Frontal area MOs integrates information from sensory cortices additively, providing a signal that is then transformed into a binary decision by a downstream accumulator.

Talk 5 - The brain represents the spatial disparity and temporal correlation of audiovisual spatial signals across the cortical hierarchies to inform multisensory causal inferences

Tim Rohe 1, Alexander Krieg 2, Ann-Christine Ehlis 2

1 Friedrich-Alexander-University of Erlangen-Nürnberg, 2 University of Tubingen

Humans integrate signals across the sensory modalities to obtain a multisensory perception of their environment if they infer that the signals arose from a common cause, but they segregate signals from independent causes. To infer the causal structure of multisensory signals, humans rely on the signals' spatiotemporal disparity and temporal correlation. Previous fMRI and M/EEG studies demonstrated that the brain represents specific causal-inference processes across the cortical hierarchies on distinct levels. Yet, it remained unclear on which cortical level and which time point the brain jointly represents the spatial disparity and temporal correlation of multisensory signals to inform causal inferences. In a combined EEG-fMRI study, we investigated how the temporal correlation and spatial disparity of audiovisual spatial signals influenced the brain's spatial representations using multivariate pattern analyses (MVPA). Participants (N = 16) localized the auditory or visual signal and judged the causal structure of the audiovisual spatial signals. Causal judgments and visual biases on auditory localization reports showed that participants inferred a common cause if the stimuli's spatial disparity was low and their temporal correlation was high. MVPA analyses of EEG and fMRI data along the cortical hierarchies demonstrated that lower levels such as visual cortex represented the signals' spatial disparity on earlier time points. Higher levels in the intraparietal sulcus encoded temporal correlation on later time points. Thus, our data suggest the brain represents the temporal correlation and spatial disparity of multisensory signals on distinct levels of the cortical hierarchies to inform multisensory causal inferences.

SYMPOSIUM #4.A
JUNE 28 | 4-5.30 PM
EINSTEIN ROOM

How spontaneous activity and sensory experience sculpt multisensory connectivity in cortical and subcortical brain regions?

Christiaan Levelt*, Huub Terra, Marta Nieto, Teresa Guillamon Vivancos, Leopoldo Petreanu

***Main organiser**

Despite the fact that what we see, hear, feel, taste and smell is processed separately by our senses, we perceive our environment as a unified and coherent whole. This is because brain regions that process the inputs from different senses are interconnected and provide contextual information to each other, allowing multisensory integration, which creates a better representation of the world than what is achieved by each sense separately. How these cross-modal inputs develop and are fine-tuned by experience has not been studied extensively.

In this symposium, we will discuss how spontaneous activity and sensory experience contribute to the development of cross-modal connectivity. Dr. Teresa Guillamon Vivancos will show how sensory inputs in superior colliculus and neocortex are initially intermingled, and how spontaneous activity and sensory experience contribute to the segregation of sensory inputs during early postnatal development. Dr. Marta Nieto will discuss how during early postnatal development, the exuberance of intracortical projections of developing cortical neurons contributes to the cortex' broad potential for diverse connectivity maps and how sensory-specific inputs eliminate these developmental projections. Dr. Huub Terra will show how auditory responses differ in primary visual cortex (V1) and higher order visual areas, and how visual experience during development influences the refinement of audiovisual crossmodal integration. Finally, Dr. Leopoldo Petreanu will demonstrate how inputs from auditory cortex to V1 are organized, what type of information about sound location is transmitted to neurons in V1 and how this contributes to the binding of spatially congruent audio-visual stimuli in the visual cortex.

Talk 1 - Perinatal spontaneous activity and its role in the segregation and acquisition of sensory modality specificity

Dr. Teresa Guillamon Vivancos 1

1 University Miguel Hernandez

Sensory perception relies on primary sensory pathways, each specialized to process a specific modality. However, it was unclear whether these pathways arise directly as unimodal or whether they are initially multimodal and become specified over time. We recently demonstrated that somatosensory and visual circuits are not by default segregated but require the earliest retinal activity to do so. In the embryo, somatosensory and visual circuits are intermingled in the superior colliculus and thus, a whisker pad stimulus leads to a cortical multimodal response: a response that engages both primary somatosensory (S1) and primary visual (V1) cortices. At birth, these circuits segregate and cortical responses switch to unimodal. This segregation depends on the arrival of stage I retinal waves to the superior colliculus.
Simultaneously to these developmental processes, cortical patterns of neuronal activity emerge spontaneously. The role of these patterns of activity in endowing cortical territories with specific sensory modalities remains unclear. Using meso-scale functional imaging in embryonic and early postnatal mice, we show that distinct sensory cortical territories exhibit specific patterns of spontaneous activity. The properties of these patterns have a divergent trajectory during development, being more similar when the circuits are intermingled, and becoming distinct from one another as circuits segregate. Furthermore, patterns of spontaneous activity rapidly change in response to sensory deprivation, reflecting underlying circuit reorganizations. Altogether, our work suggests that patterned spontaneous activity in developing cortex contains crucial information about the construction of emerging circuits and may be used to predict or modulate circuit assembly during development and disease.

Talk 2 - The development of multisensory cortical circuits

Dr. Marta Nieto 1

1 CNB-CISC

Crossmodal integration occurs both in subcortical and cortical territories. How crossmodal circuits of the cerebral cortex develop and tune has been little investigated. The talk will discuss work from our laboratory demonstrating that the cortex has broad potential for diverse connectivity maps early postnatally due to the extreme exuberance of the intracortical projections of developing cortical neurons. Adult connectivity is acquired gradually when these developmental projections are differentially eliminated under the influence of sensory-specific inputs. Our first studies investigated unimodal circuits and indicated that early exuberance and later pruning enable plasticity and robust stereotyped wiring of complex networks, a hallmark of associative crossmodal circuits. I will discuss results describing adult crossmodal auditory-visual intracortical networks and the first results of investigating their development.

Talk 3 - Role of visual experience in audiovisual integration in the visual cortex

Dr. Huub Terra 1

1 Royal Netherlands Academy of Arts and Sciences

In order for cross-modal connections in the cortex to integrate information in a way that accurately represents the environment, they must be sculpted by experience. Here we addressed the question how visual experience influences audiovisual cross-modal plasticity in primary and higher order visual areas during development and how it affects restoration of vision at a later age. To address this issue, we studied the effects of dark-rearing and subsequent visual experience on auditory and visual responses in visual cortical areas using chronic two-photon calcium imaging in mice. Preliminary results show that in higher order visual areas, auditory responses were more pronounced than in V1. We conclude that visual experience during development is required for refinement of audiovisual crossmodal integration and that a loss of visual experience results in more auditory integration in higher visual cortical regions than primary visual cortex.

Talk 4 - Non-topographic sounds localization signals in auditory cortex inputs to primary visual cortex

Dr. Leopoldo Petreanu 1

1 Champalimaud Foundation

To bind different physical features of objects, multiple sensory stimuli must be linked when they are congruent in time and space. The auditory cortex (AC) sends projections to the primary visual cortex (V1), providing a substrate for binding audio-visual stimuli based on their spatiotemporal congruence. Although AC neurons exhibit spatial auditory receptive fields, it remains unclear whether information about the spatial location of sounds is transmitted to V1 and whether they target neurons with similar receptive fields. We used dual-color two-photon calcium imaging and a 3D array of speakers and light- emitting diodes to 1) measure the auditory spatial information that the AC transmits to V1 and compared it to the visual receptive fields of their targets and 2) investigate whether multisensory interactions rely on the spatial congruence of auditory and visual stimuli. Our findings demonstrate that many AC axons relay information about the location of a sound source to V1. The location of sounds could be accurately decoded from AC axons in layer 1, providing V1 neurons with a rich substrate for making location-specific audiovisual associations. However, AC boutons in V1 were not topographically arranged, as their auditory spatial receptive fields were not related to those of their postsynaptic V1 neurons. Accordingly, audio-visual modulations of both AC axons and V1 neurons did not rely on the spatial congruence of the sound and light stimuli. Our findings show that while AC inputs are not organized in a topographical manner, they still transmit robust signals regarding sound location to V1 neurons, which provides a foundation for binding spatially congruent audio-visual stimuli in the visual cortex.

SYMPOSIUM #4.B
JUNE 28 | 4-5.30 PM
NEWTON ROOM

Multisensory processing in face-to-face communication

Stefania Benetti*, Ambra Ferrari*, Davide Bottari, David Peeters, Jamie A. Ward, Judith Holler

***Main organiser**

Complex social communication is at the core of human uniqueness. One astonishing aspect of human communication is our ability to master it, reliably and seemingly without effort, despite the intrinsic fast-changing dynamics that characterise face-to-face social interactions. From this perspective, mastering communication does not merely equal mastering speech. On the contrary, humans are faced with a fundamental computational challenge: the integration of myriads of congruent yet discontinuous multimodal signals (such as head, face and mouth movements, eye-gazing, hand gestures, speech, and non-speech sounds), which need to be interpreted as coherent and unified communicative actions, and the segregation of tangential signals that are not connected by the same communicative content. How do we achieve such an extraordinary feat? To date, this question remains largely unanswered because multisensory research on human communication has focused primarily on speech-lip signal integration. By bringing together a multidisciplinary group of speakers, this symposium proposes a theoretical and methodological shift of perspective with the aim to promote scientific progress on the neurocognitive mechanisms of human communicative interactions.

From a theoretical perspective, we will frame acts of social interaction at multiple interactive levels, thereby moving beyond the predominant focus on speech-lip integration and including other meaningful signals during naturalistic in situ communication. Crucially, we will provide complementary evidence suggesting that verbal and non-verbal communicative signals may be integrated to represent socially relevant acts through domain-general mechanisms of multimodal integration and prediction. Methodologically, we will bridge the gap between psycholinguistics, sensory and cognitive neuroscience, thereby promoting exchanges that may foster future research on the neurocognitive mechanisms of multimodal communication. We believe that, thanks to its innovative approach, this symposium proposal constitutes a highly timely and original contribution, and therefore will attract significant interest within the IMRF community.

Talk 1 - Neural tracking of speech in case of sensory obstacles

Davide Bottari 1
1 IMT School for Advanced Studies Lucca

Social communication is intrinsically multisensory. To deepen specific roles of audition and vision in this context, we combined the study of neural tracking of continuous speech with natural models experiencing impoverished sensory input. To investigate the role of audition, I will show data concerning cochlear implantation (CIs), which provides partial restoration of hearing. Yet, it is unknown whether the auditory cortex receiving sounds via CI can operate at multiple levels of analysis required to track continuous speech efficiently. Results revealed that neural tracking of continuous speech develops in CI children regardless of congenital or developmental auditory deprivation, and despite impoverished auditory input. Nevertheless, temporal profiles of neural tracking were substantially delayed. Notably, early implantation and protracted experience with the implant decreased the delay, making neural synchronisation to speech envelope in CI more like typical development and indicating a prominent role of experience. To investigate the role of vision, I will discuss how surgical masks represent a communication barrier. In examining this, I will revise some recent data revealing the detrimental impact of mouth coverage on neural tracking of speech. Overall, the study of communication with impoverished auditory or visual input offers the possibility of revealing the profound multisensory nature of communication and highlights the complex dynamics underlying the understanding of speech signals.

Talk 2 - How simple up-and-down hand movements influence speech perception

David Peeters 1
1 Department of Communication and Cognition, Tilburg University

The study of audiovisual speech perception has typically focused on the integration of visual articulatory cues (i.e., lip movements) with auditory speech, for instance exemplified in the classic McGurk effect. Moreover, most studies investigated the perception of speech segments (consonants and vowels, e.g., /ba/ vs. /ga/) since visual cues to speech prosody, such as pitch and intensity, are less readily perceived from the face.
In this talk, I argue that speech prosody is principally conveyed through other bodily articulators, focusing primarily on the timing of simple up-and-down hand gestures, known as beat gestures. I will present empirical data from my research group demonstrating that the presence of a carefully-timed beat gesture guides the perception of lexical stress (i.e., distinguishing OBject from obJECT). In fact, subtle visual articulatory cues on the face are ignored in audiovisual stress perception, highlighting distinct contributions of articulatory vs. gestural visual cues to audiovisual speech perception. The influence of simple beat gestures on stress perception is furthermore shown to trickle down to vowel perception, influencing vowel length distinctions in Dutch (e.g., tak “branch”, with short /ɑ/; taak “task”, with long /a:/). Finally, I will demonstrate that beat gestures can have a long-lasting influence on perception by recalibrating phonological
representations of lexical stress, thus changing audio-only speech perception minutes later. Together, these findings emphasise that the timing of seemingly meaningless hand movements, commonly occurring in everyday face-to-face communication, are important cues to prosody, with a pervasive influence on audiovisual speech perception.

Talk 3 - Quantifying head mimicry in conversations

Jamie A. Ward 1,2
1 Goldsmiths University of London, 2 University College London

Many studies suggest that people mimic each other's actions and postures during face-to-face conversation, but it has not been easy to quantify this behaviour or to understand the cognitive mechanisms behind it. Here, we describe a series of studies using high resolution motion capture to record head movements in pairs of strangers engaged in conversation. We test how head motion coherence varies with conversation type and individual differences, and find that mimicry of head nodding is strongest in picture-description conversations, while fast nodding is present during information-exchange conversations. No reliable patterns of individual differences could be identified, suggesting that head movements during face-to-face conversation are driven by context rather than by personality. More broadly, this work showcases new methods for tracking bodily movements and how they can be used in future research of social interaction during face-to-face multimodal communication.

Talk 4 - Human language processing as a multimodal, situated activity

Judith Holler 1,2
1 Radboud University, 2 Max Planck Institute for Psycholinguistics

The natural environment of human communication is face-to-face interaction, where communication is inherently multimodal. In this environment, interlocutors communicate via words as well as a whole plethora of visual bodily signals, including manual gestures, facial signals, gaze, head and torso movements. These signals can carry semantic and pragmatic meaning and thus form an integral part of human language. However, their role in situated communication is still rather poorly understood, especially in terms of comprehension. In this talk, I will provide a summary of some recent findings from our lab demonstrating that visual bodily signals, due to their presence and temporal organisation, have the potential to facilitate processing during language comprehension, and that one mechanism by which they may do so is the facilitation of prediction. Together, the findings advocate a multimodal, in situ framework for understanding human language and communication, and one that transcends individual visual articulators, in line with a holistic, Gestalt-based notion of multimodal perception during communication.

Talk 5 - Towards a neurocognitive model of multisensory processing in face-to-face communication

Stefania Benetti 1,2, Ambra Ferrari 3,4
1 University of Trento, 2 Interuniversity Research Center "Cognition, Language and Deafness", 3 Radboud University, 4 Max Planck Institute for Psycholinguistics

Building on previous calls for the need to study communication in its multimodal manifestation and ecological context, we offer an original perspective that bridges recent advances in psycholinguistics and sensory neuroscience into a neurocognitive model of multimodal face-to- face communication. First, we highlight a psycholinguistic framework that characterises face-to- face communication at three parallel processing levels: multiplex signals, multimodal gestalts and multilevel predictions. Second, we consider the recent proposal of a lateral neural visual pathway specifically dedicated to the dynamic aspects of social perception and reconceive it from a multimodal perspective ("lateral processing pathway"). Third, we reconcile the two frameworks into a neurocognitive model that proposes how multiplex signals, multimodal gestalts, and multilevel predictions may be implemented along the lateral processing pathway. We conclude that the time is mature to accept the challenge we, among others before, advocated in this perspective and move beyond the speech-centred perspective dominating research on the neurocognitive mechanisms of human communication and language. Testing our framework represents a novel and promising endeavour for future research.

SYMPOSIUM #5.A
JUNE 29 | 10.30-12 PM
EINSTEIN ROOM

Naturalistic movies and novel resting-state approaches; non-classical methods in plasticity research

Marcin Szwed*, Sam Nastase, Maria Zimmermann, Giacomo Handjaras, Daniel Margulies, Velia Cardin, Katarzyna Ciesla

***Main organiser**

Complex social communication is at the core of human uniqueness. One astonishing aspect We will discuss and debate non-classical methods in plasticity research, naturalistic movies and novel resting-state approaches. Cognitive neuroscience has traditionally relied upon relatively simple parametric tasks using abstract stimuli, delivered in a strictly controlled manner. However, when stringent design considerations constrict both hypotheses and data, we risk missing the proverbial elephant in the room. Over the last decade, naturalistic stimuli and novel resting-state approaches have become a complimentary way of studying the brain. Recently, they began to be applied in the cross- modal plasticity field, where they bring the promise of uncovering new phenomena yet undiscovered with the classical approaches.

In this symposium, two illustrious guests (Nastase/Margulies) from outside of the multimodal community will present their latest findings from the frontiers of the naturalistic/computational approaches. Their talks will intertwine with talks by early- and mid-career researchers who are using resting-state fMRI and naturalistic stimuli such as the “101 Dalmatians” and “The Triplets of Belleville”, to study cross-modal plasticity in deaf, blind, hearing and sighted subjects. The symposium represents a unique occasion to generate fresh ideas. It will also be an occasion to create new MRI data-pooling consortia. Together, we hope to provide the audience with the latest update of key insights into the fundamental ability of the brain to reorganize itself when experiencing sensory loss, and how it can be studied with non-classical methods.

Talk 1 - Learning a shared linguistic space for transmitting our thoughts to others

Sam Nastase 1
1 Princeton University

We use language to organize and communicate our thoughts to others. Natural language, however, is fundamentally contextual, making it unamenable to experimental control. In this talk, I argue that the large language models emerging from machine learning community are an important for a more ecological neuroscience of language. These self- supervised models learn the rich, context-sensitive structure of language from real-world examples, allowing us to quantify contextual meaning in a way previously inaccessible. I provide examples of how these models can provide novel insights into the neural machinery for human language and communication. First, I show how we can deconstruct internal circuits of these models to directly access the computations—or “transformations”—that sculpt the unique meaning context. I show that these transformations provide a window onto linguistic computations in the brain using fMRI data recorded while subjects listened to spoken stories. Critically, we can also disassemble these transformations into functionally-specialized sub-computations and map these them onto the language network. Second, I show how we can position these models as intermediaries for translating neural activity from one brain to another. In ongoing work, we use contextual embeddings to capture the linguistic content of brain-to- brain coupling during spontaneous conversations between pairs of ECoG patients. We show that content in the speaker’s brain prior to word articulation (re)emerges in the listener’s brain after articulation word-by-word in natural conversations. These findings suggest that large language models key into the same context-sensitive linguistic space that human speakers use to transmit their thoughts to others.

Talk 2 - Auditory areas are recruited for naturalistic visual meaning in early deaf people

Maria Zimmermann 1
1 Jagiellonian University

Congenital deafness enhances responses of auditory cortices to non-auditory tasks, yet the nature of the reorganization is not well understood. Here, naturalistic stimuli were used to induce neural synchrony in early deaf and hearing individuals. Participants watched a dialogue-less animated film (“The Triplets of Belleville”) in an intact version and three versions with gradually distorted meaning.
Differences between groups were observed in higher-order auditory cortices in all stimuli, with no significant effects in the primary auditory cortex. Comparison between levels of scrambling revealed a heterogeneity of function in secondary auditory areas. Both hemispheres showed greater synchrony for the intact movie than for low-level variants. However, the right hemisphere showed an increased intersubject synchrony for the low- level movie variants, which was not present on the left. An event segmentation validated these results: the dynamics of the right secondary auditory cortex unfolded as shorter length events with more transitions than the left. It also uncovered a further left-right asymmetry: Only left-hemisphere patterns matched the patterns of the hippocampus, a brain region situated at the top of cortical hierarchy. Our results reveal how deaf subjects use their auditory cortex to process visual meaning.

Talk 3 - Measuring functional reorganization in congenital sensory deprivation using naturalistic stimulation

Giacomo Handjaras 1
1 IMT School for Advanced Studies

Alterations in sensory input availability affect cortical organization across various species. Yet, it is unknown to what extent the type of the missing sensory input determines different degrees of plastic adaptation in the human brain. The present contribution directly tackles this issue by comparing cortical alterations in congenitally blind and deaf individuals to uncover shared or distinctive features of hearing- and sight-dependent cortical plasticity. By using functional magnetic resonance imaging (fMRI) during the presentation of an audiovisual, audio-only or video-only version of the same narrative in distinct groups of sensory-deprived and typically developed individuals, we measured Inter-Subject Correlation (ISC) as a proxy of neural activity and plastic reorganization. Moreover, to provide a fine-grained characterization of the ISC, we applied computational modeling to our naturalistic stimulation, by extracting perceptual features from both the auditory and visual streams, and semantic properties of the narrative from large language models. As results, we observed both patterns of greater and reduced synchronization profiles in congenitally blind and deaf participants compared to typically developed ones. Remarkably, occipital regions showed greater synchronization in both congenital visual and auditory deprivation relative to typical development. On the contrary, in both models of sensory deprivation, we found a decreased engagement of the temporal areas, although here blind and deaf individuals showed distinct patterns of functional reorganizations. Findings support the hypothesis of an intrinsic organizing principle in the human brain in which the visual system possesses a greater degree of plasticity than the auditory one.

Talk 4 - Mapping sensory convergence in the functional connectome

Daniel S. Margulies 1
1 University of Paris

What is the role of sensory integration in establishing functional hierarchies with the cerebral cortex? Previous research has described a principal gradient of cortical organization extending between sensorimotor and associative systems. Here we investigate how the integration across different sensory modalities contributes to the emergence of distinct functions within association cortex. We will present recent work on a sensory convergence model of organization across the cortical hierarchy based on the analysis of MRI data. Using movie-watching paradigms, we observed that sensory modalities are further differentiated from one another within the embedding space. This suggests the utility of naturalistic paradigms for characterizing sensory differentiation and convergence across the global hierarchy. We will discuss these results in conjunction with related analyses of functional hierarchies in blind individuals, where we have observed relative shifts within the visual system. Taken together, these results will be discussed in the context of global processing hierarchies and the context-specific impact of sensory input on higher-order regions.

Talk 5 - Resting state connectivity differences in deaf and hearing individuals

Velia Cardin 1
1 University College London

Sensory experience profoundly impacts sensory and cognitive processing in the brain, including the organisation of functional brain networks. In this talk, I will present work describing the effect of early deafness on the organisation of resting-state networks of the human brain and its relation to executive processing. Our results show significant differences between early deaf and hearing individuals in the connectivity between the auditory network and the somatomotor and salience/ventral attention networks of the brain. We also found significantly different associations between resting connectivity and performance in executive function tasks in deaf and hearing individuals. These findings indicate that sensory experience influences not only the organisation of sensory networks, but that it also has a measurable impact on the organisation of association networks supporting cognitive processing.

Talk 6 - Resting-state network changes following training of audio-tactile speech understanding

Katarzyna Ciesla 1, 2
1 Reichman University, 2 Warsaw Institute of Physiology and Pathology of Hearing

Speech in noise understanding is a challenging task, especially for the hearing-impaired. We developed a multisensory set-up for training speech comprehension that combines auditory and vibrotactile inputs delivered on fingertips. Seventeen individuals with normal hearing participated in a 30-45 min Training session and a 10min resting state exam in a 3T Siemens Skyra MR scanner. There was mean group improvement of 10dB in Speech Reception Threshold (for 50% understanding) in comprehension of sentences paired with low-frequency vibrations. RsfMRI results showed enhanced functional connectivity before Training between bilateral inferior lateral occipital cortex (LOC) & left insula, and between bilateral superior temporal lobes (auditory cortex) & right inferior LOC/occipital pole. After training enhanced connectivity was found between the occipital pole (early visual cortex) & the left superior parietal lobe/supramarginal gyrus/posterior central gurus (sensory/multisensory cortex). We suggest that the functional connectivity changes reflect two types of switching mechanisms following audio-tactile training : 1. from an automatic mode of employing the audio-visual speech network (e.g. lip reading) when attempting to understand a challenging speech signal, to a mode of integrating new reliable tactile inputs, 2. from spatial tactile object recognition (of the vibration sources) to understanding the content of the vibrotactile inputs. The results can be interpreted in the framework of novel sensory learning in adulthood and have important implications for the development of assistive aids for the hearing (but also sight) impaired population.

SYMPOSIUM #5.B
JUNE 29 | 10.30-12 AM
NEWTON ROOM

Recent advances in multisensory research methods

Meike Scheller*, Peter Scarfe, Nick Prins, Rebecca Hirst, Micah M. Murray, Ioannis Delis

***Main organiser**

Determining how the human brain unifies information from different senses into a coherent perceptual representation depends on the constant development and refinement of measurement tools and analysis methods. As such, the precision and robustness of our findings is typically contingent on the precision and robustness of the methods we use to quantify multisensory processes. This symposium will outline recent advances in existing and novel multisensory research methods by (1) updating and refining established methodologies, (2) introducing new tools and approaches, such as parameter estimation techniques, online research instruments, and brain measurement methods:

Firstly, we provide a review and update on crucial developments in methods that are frequently used in the field. Scheller & Nardini will outline why selecting the wrong comparator when testing for cue combination can lead to erroneous conclusions. Scarfe will introduce a computationally attainable method to experimentally disambiguate cue combination from alternative perceptual strategies.

Secondly, we introduce new methods and tools for measuring and modelling perception, both at behavioural and neural levels. Prins will provide a theoretical and practical introduction to testing research hypotheses efficiently and robustly via model reparameterization with the Palamedes Toolbox. Hirst et al. will provide an update on recent developments in studying multisensory perception in online contexts using the platform PsychoPy. Moving to methods that study the neural processing basis of multisensory perception, Murray will provide an overview of recent developments in EEG/fMRI methodologies to study multisensory perception. Finally, Delis will describe a new model-based decoding approach to relate EEG signals to predictions about multisensory decision processes and quantifying representational interactions in the human brain.

By updating the IMRF audience with advances in key methods, and introducing novel tools and analysis techniques, this symposium aims to equip the broad multisensory community with the tools to investigate perceptual processes in powerful new ways.

Talk 1 - Of power and pitfalls when testing for cue combination

Meike Scheller 1, Marco Nardini 1
1 Durham University

When studying multisensory processes, we are often interested in how humans combine information (cues) across, or sometimes even within, the senses. Of central interest is the potential precision benefit gained by cue combination. Over the last two decades, many studies showed individuals to gain perceptual precision when given combined vs single cues, consistent with combining them in proportion to their reliabilities. That is, more reliable cues are weighted more strongly than less reliable cues in the final estimate. A measured precision benefit serves as key behavioural evidence that this kind of cue combination is taking place. However, reliably measuring any precision benefit is not trivial. Firstly, we show the importance of checking that, if observers did optimally combine cues by their reliabilities, the maximum predicted benefit is not smaller than the error inherent to our measurements. Hence, careful selection and calibration of stimuli and task design are crucial to enhance the power with which we can distinguish cue combination from alternative perceptual strategies. Furthermore, past studies used different analysis approaches to demonstrating cue combination, however, currently no guidelines exist that suggest which of these approaches is superior. Here we show that the most frequently used analysis approach suffers from strong alpha error inflation, potentially leading us to wrongly conclude that cues were combined when, in fact, observers followed the best single cue. Overall, we will review the approaches that have been used, and provide recommendations for future studies aiming to reliably measure cue combination.

Talk 2 - Experimentally disambiguating models of sensory cue integration

Peter Scarfe 1
1 University of Reading

It is generally accepted that humans integrate sensory cues, both within and across modalities, in a “statistically optimal fashion”. Problematically many alternative algorithms/models exist by which to integrate cues and many could be considered equally “optimal” based upon different criteria. Furthermore, these models often provide highly correlated predictions to one another and most experimenters negate the assumptions made in experimentally testing their preferred model and fail to consider alternative models by way of model comparison. Here I present evidence regarding the impact this has on providing evidence for how humans integrate sensory cues. I describe a computationally simple way in which, for a given experimental design, one can determine the probability with which the performance of observers behaving in accordance with one candidate model can be distinguished from a set of alternative models. This takes into account the end-to-end design of the experiment, from data collection, model fitting, through to statistical analysis. The technique is generalisable to any type of experimental design and will aid experimenters in making robust conclusions about data adhering to the predictions of a given model (both in cue integration and beyond).

Talk 3 - A gentle introduction to the use of model reparameterization to target specific research hypotheses in the Palamedes Toolbox

Nick Prins 1
1 University of Mississippi

The Palamedes Toolbox (www.palamedestoolbox.org) is an extensive set of statistical routines that can be used to analyze data from a wide variety of psychophysical experiments. A recent addition to the toolbox allows users to fit psychometric functions (PFs) to data obtained across multiple conditions and participants using a hierarchical Bayesian approach. Users are given considerable flexibility to specify models in order to target specific research questions regarding the effect of experimental manipulations or to reduce model complexity. Simple model specifications (e.g., constraining lapse rates to be equal across conditions) as well as simple comparisons between pairwise conditions (e.g., 'is there evidence that slope parameters differ between conditions 1 and 2?') can be implemented in Palamedes using verbal commands. More involved comparisons (e.g., 'do experimental manipulations A and B interact in their effect on the PF's location parameter?') are possible also but require the user to supply model specifications in the form of model matrices. The model matrices serve to reparametrize the model. Here, a simple example experiment with data obtained from human observers will be used to illustrate how model matrices can be designed and used in order to target specific, theoretically motivated hypotheses. Moreover, it is demonstrated that the resulting model reparameterizations separate the targeted experimental effects from the effect of individual differences thereby revealing evidence for the targeted effects which the individual differences would have otherwise obscured. Throughout, analogies will be drawn to statistical procedures with which many researchers may be more familiar (t-test, factorial ANOVA).

Talk 4 - Considerations for running multisensory experiments online

Rebecca Hirst 1,2, Kimberley Dundas 1, Leon Flanagan 3, Nina M. Zumbrunn 3, Alan O'Dowd 2, Martina Seveso 2, Nikita A. Agafonov 1, Alain Pitiot 1, David P. McGovern 3, Fiona N. Newell 2, Jonathan Peirce 1,4
1 Open Science Tools LTD, 2 Trinity College Dublin, 3 Dublin City University, 4 University of Nottingham

Online experiments run via the browser are becoming increasingly popular and online studies open the doors to new avenues in perception science, enabling large-scale studies and access to populations that typically may not be able to attend "in lab". Multisensory researchers, however, face unique challenges. Here we'll discuss potential problems, and solutions, for running multisensory experiments online. First, many multisensory experiments require precise control of timing of multi-modal stimuli, but how good is the temporal precision and accuracy of online stimulus presentation? We examine the timing of visual, auditory and vibrotactile stimulus delivery as well as outlining data validating behavioural phenomena known to rely on precise audio-visual timing, the Sound Induced Flash Illusion. A second issue is that multisensory integration is influenced by relative stimulus intensity - but how can we control stimulus intensity "in the wild". In audition, your participant has means to record stimulus intensity and background noise level. In vision, stimuli may require luminance modulation across a linear scale, which requires gamma correction, but how do we measure the gamma value we require if our remote participant doesn't have a photometer, and how can we actually set gamma, given that browsers don't have access to the hardware Look-Up Table? We'll present data showing how PsychoJS solves the problems of gamma correction via rapid psychophysical calibration. We'll show how multisensory research online is possible, and facilitated via several novel solutions, whilst outlining the practical considerations and caveats that researchers should be aware of when making the leap online.

Talk 5 - From old dogs to new tricks: brain mapping and imaging methods for multisensoryresearch

Micah M. Murray 1-3
1.Radiology Department, Lausanne University Hospital and University of Lausanne, Switzerland
2.The Sense Innovation and Research Center, Lausanne and Sion, Switzerland
3.CIBM Center for Biomedical Imaging, Lausanne, Switzerland

This talk overviews innovations in both EEG and MRI/fMRI that impact contemporary multisensory research. First, the electrical neuroimaging framework for EEG analyses will be summarized. Electrical neuroimaging is mathematically straightforward and allow researchers to circumvent interpretational challenges of canonical EEG/ERP analyses. Of particular benefit for multisensory research is the ability to leverage the added information from high-density EEG recordings to differentiate between modulations in response strength and response topography in a reference-independent manner that in turn facilitates inter-individual and inter-site standardization. Second, novel anatomical MRI sequences for imaging moving bodies (biomechanical MRI) are introduced. Biomechanical MRI acquires 3-dimensional images while the eye freely moves. Eye motion serves as the basis for image reconstruction, rather than an impediment. Biomechanical MRI not only allows for motion-robust imaging, but also allows for high-resolution understanding of how movements are controlled. Finally, whole-brain, high spatial and temporal resolution functional MRI (Hi-Fi fMRI) will be presented. Hi-Fi fMRI overcomes many trade-offs of standard EPI sequences. It measures BOLD signals with a gradient recalled echo (GRE) with 3D radial-spiral phyllotaxis trajectory at a high sampling rate (28.24ms) on standard 3T field-strength. The framework enables the reconstruction of 3D signal time courses with whole-brain coverage atm simultaneously high spatial (1mm3) and temporal (250ms) resolutions.Collectively, biomechanical MRI and Hi-FI fMRI open new opportunities for ethologically-valid and naturalistic paradigms, the inclusion of populations typically unable to stably fixate or remain immobile, and increased translational research (e.g. in awake animals whose eye movements constitute an accessible behavioural readout).

Talk 6 - Neurally-informed cognitive modelling of multisensory processing

Ioannis Delis 1
1 University of Leeds

I will present a novel approach to the study of multisensory processing in the human brain by combining state-of-the-art Electroencephalography (EEG) with advanced multivariate data analysis and computational modelling. This approach intercepts neural signals and relates them to behavioural outcomes of multisensory processing on a trial-by-trial basis. To demonstrate its functionality, we applied this methodology to experimental paradigms investigating audio-visual and active visuo-haptic processing, as well as implicit cross-modal associations. I will summarise key findings from these studies, offering insights into the strengths of our approach. First and foremost, the neurally-informed cognitive modelling approach does not only yield more accurate cognitive models but can also lead to the identification of latent cognitive states and their neural correlates, which are otherwise unobservable with conventional (non-neurally constrained) modelling approaches. Therefore, we can associate multisensory benefits with the neural processes underpinning them. Second, jointly modelling electrophysiological and behavioural measures allows single-trial behavioural outcomes to be associated with temporally-specific EEG components, offering insights into the temporal order of brain processes underlying the observed multisensory effects. Finally, by contrasting the model predictions between sensory conditions, we can quantify cross-modal interactions in the human brain. This enables the identification of supramodal neural representations (i.e., invariant to the sensory modality) as well as neural representations of multisensory gains (i.e., sensory evidence enhancements as a results of multisensory information). These cannot typically be characterized or quantified using traditional “additive model” approaches.

SYMPOSIUM #6
JUNE 29 | 2-3.30 PM
EINSTEIN ROOM

Post-natal transient blindness : how does the visual system cope with it ?

Stefania Mattioni*, Ehud Zohary, Marc Ernst, Rashi Pant

***Main organiser**

Vision has always served as a privileged model to study how the brain develops. Despite decades of research, fundamental questions remain regarding how the visual system develops its functional tuning to some specific visual features or domains.

Transient sensory deprivation early in life due to congenital cataracts, represents a unique model to address these questions. Indeed, it causally tests the impact of early sensory experience vs innate factors in shaping the development of visual abilities and the functional tuning of brain regions. The nature-nurture question here is whether postnatal development depends on experience or develops after birth according to a built-in program.

The aim of this symposium is to bring together a multifaceted group of scientists who combined advanced psychophysical and neuroimaging methods with sight restoration models to disentangle how sensory experience shapes the development of visual functions and the functional tuning of the brain visual network.

E.Zohary will focus on the development of visual functions in children who were deprived of normal vision for many years since birth. M.Ernst will emphasize the role of vision for fine motor control and the developmental trajectory of visual perception abilities for action capacities following cataract removal. The next talks will zoom into the alteration of visual cortex following bilateral congenital cataracts' removal. R.Pant will delve into the reduction of EEG resting-state and stimulus-evoked alpha oscillations after cataract-reversal, likely indicating deficient recurrent processing in the visual hierarchy. S.Mattioni, using fMRI, will show the impact of a transient period of visual deprivation early in life on the development of the visual categorical organization from the early visual cortex to the ventral visual pathway.

Why sensory loss triggers such functional changes and brain reorganization? In the last talk P.Sinha will address this fundamental question exploring the teleology behind cortical reorganization following sensory loss.

Talk 1 - The possibilities and limits for visual function recovery after prolonged blindness from birth

Ehud Zohary 1, Tanya Orlov 1, Ayelet Mckyton 1, Itay Ben-Zion 1, Ravid Doron 1, Sara Attias 1, Yuval Porat 1, Ilana Naveh 1, Asael Y. Sklar 1, Daniel Harari 2, and Shimon Ullman 2

1 Hebrew University, 2 Weizmann Institute of Science

My talk will be focused on the development of vision functions in children who were deprived of normal vision for many (5-20) years since birth, due to long- standing untreated bilateral congenital cataracts. Before surgery, these patients typically have extremely limited visual acuity (~1cpd) and no pattern vision. After surgical treatment, their spatial vision improves substantially (mean ~6-7 cpd), but is still far from normal level (30cpd). However, despite sustaining a long deprivation period and their remaining image blur, these patients typically show dramatic improvement after surgery: They are now able to recognize objects and manipulate them; they seamlessly navigate around obstacles, and they no longer behave like blind people. They also improve in some challenging visual tasks, such as judging the shape of an object moving behind a narrow slit, when only a tiny fraction of it is visible at any instant. Collectively, these results indicate that vision restoration after prolonged early-onset blindness is feasible to a greater extent than previously thought.
However, the patients still have some deficiencies, mainly in understanding and responding to social cues. For example, unlike early-treated cataract patients, the late- treated patients do not follow the gaze of others, despite gaining sufficient visual acuity after surgery to judge the pupil position of others. We suggest (and verify using a computational model) that visual skills acquired in infancy in an unsupervised manner will be difficult or impossible to acquire when internal guidance is no longer available, even when sufficient image resolution for the task is restored.

Talk 2 - The development of vision for action after sight restoration from congenital cataracts

Marc O. Ernst 1, Sophia Piller 1, Irene Senna 1

1 Ulm University

The predictive nature of vision is important in the control of adept bodily actions, such as grasping, walking, or pointing. The development of such fine motor control typically occurs within the first months to years of life. Without structured vision, this development is impaired. If we were able to restore structured vision later in life, however, would it be possible to still develop adult-like predictive fine motor control? To test this question, we had the unique chance to conduct experiments with Ethiopian children (aged 6 to 20 years) who were born with bilateral dense cataracts and who were operated later in life to restore structured vision. In this talk I will report on several studies we have conducted investigating perception for action capacities and their development over roughly the 3 years we were able to follow their developmental trajectory. For example, we could show that the calibration of visuomotor behavior developed slowly within the first two years after eye surgery, while natural predictive grasping behavior relying on feed-forward control of action did not. Other tasks such as using vision in the control of balance also seemed to show a slow developmental trajectory. Comparing these tasks to earlier reports on the development of vision and multisensory perception suggests that the development of vision for the control of action might be hampered particularly strongly by an early onset visual deprivation.

Talk 3 - Stimulus-evoked and endogenous alpha oscillations show a linked dependence on patterned visual experience for development

Rashi Pant 1, José Ossandon 1, Liesa Stange 1, Idris Shareef 2,3, Ramesh Kekunnaya 2, Brigitte Röder 1

1 University of Hamburg, 2 LV Prasad Eye Institute, 3 University of Nevada

Visual impairments after delayed removal of dense bilateral congenital cataracts have been attributed to altered visual cortex development within a sensitive period. One observed difference in neural activity after cataract-reversal was the reduction of occipital alpha (8- 14 Hz) oscillations during visual motion tasks. However, it was unclear whether reduced alpha oscillations were task-specific, or whether they were linked to impaired visual behavior in cataract-reversed individuals. We compared resting-state and stimulus-evoked alpha activity between individuals who had been treated for dense bilateral congenital cataracts (CC, n = 13, mean duration of blindness = 11.0 years, Range = 0.2-31.6 years) and age-matched, normally sighted individuals (SC, n = 13). The visual impulse response function was adapted from Vanrullen & MacDonald (2012) to test for the characteristic alpha response to visual white noise. Participants observed white noise stimuli changing in luminance with equal power at frequencies between 0-30 Hz. CC individuals demonstrated a reduced likelihood of exhibiting an evoked alpha response compared to SC individuals. Moreover, stimulus-evoked alpha power was reduced, and correlated with a corresponding reduction of resting-state alpha power in CC individuals. Finally, CC individuals with an above-threshold evoked alpha peak had better visual acuity than CC individual without an evoked alpha peak. Since alpha oscillations have been linked to top-down communication, we suggest that the concurrent impairment in resting-state and stimulus-evoked alpha oscillations indicates an altered interaction of top-down and bottom-up processing in the visual hierarchy, likely contributing to incomplete behavioral recovery in individuals who experienced transient congenital blindness.

Talk 4 - Categorical coding in the ventral occipito-temporal cortex (VOTC) following transient early blindness

Stefania Mattioni 1, Mohamed Rezk 2, Xiaoqing Gao 3, Junghyun Nam 3, Zhong-Xu Liu 3, Remi Gau 2, Valérie Goffaux 2, Terri Lewis 4,5, Daphne Maurer 4,5, Olivier Collignon 2,6

1 Ghent University, 2 UCLouvain, 3 Zhejiang University, 4 University of Toronto, 5 McMaster University, 6 The Sense Innovation and Research Center

It has been suggested that a transient period of postnatal visual deprivation affect the development of object categorization in the visual system. Here we overturn this assumption by demonstrating typical categorical coding in the ventral occipito-temporal cortex (VOTC) despite early visual deprivation and pervasive alteration in the functional response in the early visual cortex (EVC). We used fMRI to characterize the brain response to five visual categories (faces, bodies, objects, buildings and words) in a group of cataract-reversal individuals who experienced a short and transient period of blindness early in life, and in a group of control participants with typical visual development. Using a combination of uni- and multi-variate analyses, we show that the encoding of low-level visual properties of our stimuli is impaired in EVC in cataract-reversal participants, while there is a preservation of the categorical response in the VOTC. When altering the visual properties of our stimuli to mimic in controls the deficit of EVC response of the cataract, we observe a cascading alteration of the categorical coding from EVC to VOTC that is not observed in the cataract-reversal group. Our results suggest that we do not need visual experience early in life to develop the typical visual categorical organization in VOTC, even in the presence of impaired low-level visual processing in EVC. These results challenge the classical view of a feedforward development of categorical selectivity in VOTC according to which the categorical organization of high-level regions depends on low-level visual protomaps.

SYMPOSIUM #7.A
JUNE 29 | 4-5.30 PM
EINSTEIN ROOM

The intimate interplay of movement and touch

Matej Hoffmann*, Luke Miller, Lucile Dupin, Konstantina Kilteni, Tobias Heed

***Main organiser**

The mechanisms of how we reach towards objects that we perceive visually have been extensively studied. In contrast, reaching to targets on the body, based on only tactual information, has been much less explored. Theories suggest that localizing targets on the body requires integrating somatosensory – that is, tactile and proprioceptive – information with an implicit model of body size. This integration, termed tactile remapping, allows localizing stimuli in external coordinates and generating movements toward the stimulus. However, recent research suggests that this “serial processing” view may be too simple. Rather, movement and touch appear to interact dynamically and bidirectionally. Our symposium, made up of 5 speakers (2 female, 3 male, 3 junior, 2 senior) will provide an action-oriented perspective on somatosensory processing and representation during movement.

We highlight tactile-motor interaction from multiple perspectives: the dynamic modulation of tactile processing during movements to self-touch (Kilteni); dynamic modulation of reference frame coding during movement towards touch (Heed); the informative role of movement in tactile perception (Dupin); the use of tools for tactile localization in sighted and blind humans (Miller); and the development and computational modeling of self-touch and reaching to one's own body (Hoffmann).

Talk 1 - Predictive modulation of tactile processing during movements to self-touch

Konstantina Kilteni 1
1 Karolinska Institutet

Self-touch feels less intense and less ticklish than the same touch applied externally. Motor control theories have suggested that cerebellar internal models predict the somatosensory reafference and attenuate, or even cancel, the perception of the actual touch. Despite this influential theoretical framework, little is known about the details of this predictive attenuation phenomenon. In this talk, I will discuss recent experimental findings from our lab showing that the attenuation of self-touch is a predictive phenomenon that builds up before our body parts get in contact, is present also if we unexpectedly miss the contact with our body, and gets perturbed in presence of prediction errors regarding the time of sensory feedback.

Talk 2 - Dynamic spatial coding in parietal cortex for planning movement towards touch

Tobias Heed 1
1 University of Salzburg

Current models posit that movements towards touch on the body are based on recoding tactile skin location with body posture information to compute an external movement goal location. Tactile processing and movement planning both rely on posterior parietal cortex (PPC) but their interplay is not understood. I present a study in which human participants pointed towards or away from memorized tactile stimuli on their feet, dissociating sensory and motor locations. Participants crossed or uncrossed their feet to dissociate stimulus location relative to anatomy versus in external space. We observed that tactile location was coded anatomically in anterior PPC but spatially in posterior PPC during sensory processing. After movement instructions were specified, PPC exclusively represented the movement goal in space, in regions closely matching those that mediate visuomotor planning and with regional overlap for sensory, rule-related, and movement coding. Thus, PPC flexibly updates its spatial codes to accommodate rule-based transformation of arbitrary sensory input to generate movement to environment and own body alike. I discuss in how far these findings support the tactile recoding view and present alternative views.

Talk 3 - How movement shapes spatial perception of touch (and vice versa)

Lucile Dupin 1
1 Integrative Neuroscience & Cognition Center

In daily life, what we touch is usually larger than the sensory surface in contact with it. Therefore, when we try to extract spatial characteristics of an object by touch—for instance its shape—we make exploratory movements such as moving the hand along the edge of the object. These movements, by spatially organizing the tactile information, allow retrieving a sufficient amount of information in order to reconstruct the shape of the object. In this case, tactile information is interpreted by the brain depending on the concomitant movement done to retrieve it. On one hand, movement appears to be a key component of spatial tactile perception. On the other hand, movements produce somatosensory feedback that can be used for correcting the movement and modifying it. Self-touch is a particular circumstance where the spatial extent of movement and its somatosensory consequence are closely linked. In fact even before birth, self-touch behaviours have been observed. Self-touch links directly a movement amplitude to a tactile consequence in the somatosensory space and could be used by the brain as a means of spatial calibration between touch and movement. We used different behavioural methods based on the paradigm of decorrelating the movement and its sensory consequence in order to study how movement shapes the spatial representation of touch, but also how touch and movement are reciprocally calibrated during self-touch.

Talk 4 - Active tactile perception during tool use in sighted and blind participants

Luke E. Miller 1
1 Radboud University

Tactile events often occur outside the body and on external objects. For example, tools can be used to extend tactile perception beyond the body—the paradigmatic example being when a blind person augments their loss of vision by using a cane to pick up information about their surroundings. We recently found that sighted participants can accurately localize where an object touches a tool when they actively contact it. Localization performance drops when tool-object contact is passive, suggesting that motor variables (e.g., efference copies) play a role in forming the spatial percept. Despite being the paradigmatic case, whether blind cane-users outperform sighted participants in tool-sensing abilities is at present unknown. To fill this gap, we compared sighted and blind participants on their ability to localize an object with a tool in both active and passive sensing conditions. To do so, we developed a novel paradigm that allowed participants to haptically report where an object touched the tool. Consistent with our prior findings, localization was more accurate and precise during active sensing compared to passive sensing. Surprisingly, we found no difference in performance in the sighted and blind participants in either condition, even though our blind participants were proficient at using their cane. We discuss these results in the context of proficient internal models of tool dynamics that can be employed during tool sensing to accurately localize objects in space.

Talk 5 - Reaching to the body: development and computational modeling

Mattej Hoffmann 1
1 Czech Technical University

We observed infants between 3 and 8 months of age in three different contexts: spontaneous activity, reaching to vibrotactile targets on the body, and reaching to toys. In the reaching to targets on the body paradigm, we additionally compared sighted and visually impaired infants. We employed state-of-the-art computer vision methods to extract 3D movement kinematics of the infants. Together, this provides a unique quantitative window into the relationship of spontaneous self-touch, active exploration of the body, reaching to targets on the body and reaching to external objects and how they unfold during development.
With the infant movement trajectories as input, we used motion retargeting to map them onto baby humanoid robots. These possess morphologies – physical characteristics as well as sensory and motor apparatus – that are akin to human bodies and can thus be used to expand the domain of computational modeling by anchoring it to the physical environment and a physical body and allowing for instantiation of complete sensorimotor loops. In particular, our robots have body proportions and limb structure modeled after infants, proprioception, binocular vision, and pressure sensitive electronic skins covering large areas of their bodies. The infant movements retargeted to the robot, together with the motor, proprioceptive, visual, and tactile signals, provide a first-person perspective on the experience in different contexts and at different ages. This sensorimotor stream is fed into biologically inspired learning algorithms. We develop models of primary proprioceptive and tactile representations on the robot, active tactile exploration, and reaching to the self and to objects.

SYMPOSIUM #7.B
JUNE 29 | 4-5.30 PM
NEWTON ROOM

The development of audiotactile and visuotactile integration for human body representations from infancy to adolescence

Maria Bianca Amadeo*, Monica Gori*, Andrew J. Bremner, Dorothy Cowie, Meike Scheller

***Main organisers**

The ability to integrate information across multiple senses develops from infancy to adulthood. This process is crucial as it scaffolds embodiment and multiple independent perceptual skills. However, to fully understand the development of the multisensory integrations underlying body representations, it is necessary to account for the development of each sense individually and bodily changes during growth. While much research has considered the development of audiovisual integration, fewer studies investigate the audiotactile and visuotactile interactions which are crucial in underpinning the emerging bodily self. In this symposium we bring together expert researchers to present the latest data and interpretation of how infants (healthy and visually impaired), children and adolescents combine touch and other sensory modalities to construct coherent representations of the body and the world at hand.

Andrew Bremner will present results about the development of audiotactile and visuotactile integration and the early origins of body representations in typically developing human infants. Monica Gori will deepen this topic by examining the role of visual experience via comparisons of audiotactile integration in sighted ad visually impaired infants and children. Next Dorothy Cowie will focus on the development of body representations in childhood, by considering the role of visuotactile congruence in children's sense of own-body position and body ownership. Two more presentations will then demonstrate the development of audiotactile integration during childhood and adolescence, which is when the body rapidly matures and grows. Specifically, Meike Scheller will present results about the development of the audio-haptic integrations underpinnings of children's perception of object size.

Together, the symposium contributes to building a coherent picture of the development and constraints of multisensory processing, which underlies complex and coherent perceptual representations from infancy to early adulthood.

Talk 1 - Development of audiotactile and visuotactile space in human infancy

Andrew J. Bremner 1
1 University of Birmingham

Research into audiotactile and visuotactile associations and integrations in human infancy promises to yield important insights into the early developmental origins of body representations. However, current research evidence has been used to support two quite distinct developmental accounts. On one hand it has been argued that infants have an innate sense of the bodily self (e.g., Rochat, 2010), and on the other it is proposed that we form complete representations of our body representations through experience dependent associations between auditory, visual and tactile cues concerning the body and limbs (De Klerk et al., 2021). In this talk I will argue that neither of these arguments can account for all of the available data. I will draw a contrast between data, including our own findings, demonstrating early competence in forming associations between auditory, tactile and visual cues (Begum Ali et al., 2021; Thomas et al., 2019; Rigato et al., 2019; Rochat, 1998), and data indicating a much more extended development across the first year for orienting responses and dynamic updating of somatosensory locations across changes in limb posture (Bremner et al., 2008; Rigato et al., 2014). On the basis of these contrasting findings, I will argue that early representations of visuotactile and audiotactile associations do not necessarily support a coherent representation of the bodily self, and that further research into the development of visuotactile and audiotactile spatial integration is needed to shed light on the early origins of body representations in human infancy.

Talk 2 - The role of vision in audio-tactile space representation

Monica Gori 1
1 Italian Institute of Technology

We rely on integrated spatial representations we build during infancy to interact with the world surrounding us. The visual experience is crucial for integrating sensory signals in a coherent configuration, considering the changes in body position in space. When vision is absent, as in the case of blind infants, how audio-tactile space representation develops is still unclear.
In the talk, I'll present results to identify the specific developmental periods when visual experience is crucial in establishing multisensory associations between sensory modalities. I'll show results about audio-tactile space representations in blind infants, blind children, and blind adolescents considering the developmental windows when spatial skills are acquired in sighted children.
By elucidating these aspects, I'll bring some input into the knowledge of spatial representations to determine how visual experiences shape their development. In the last part of the talk, I'll show a new quantitative methodology to restore through multisensory training the coherent spatial representations of blind children and adults and some input for early intervention in blind infants.

Talk 3 - The role of visuotactile congruence in childhood own-body representation

Dorothy Cowie 1, Hayley Dewe 1, Laura A. Bird 1, Marco Gillies 2, Jane Aspell 3, Andrew J. Bremner 4

1 Durham University, 2 University of London, 3 Anglia Ruskin University, 4 University of Birmingham

What is the role of this visuotactile congruence in children's own-body representation? Here we present an analysis of several datasets which speak to this question. In each case, we used visuotactile congruence to induce an illusion of body ownership over a fake hand or virtual body, in children (4-14 years) and adults. Datasets include the rubber hand illusion in classic form (Cowie et al 2016, n=180), with rotated hands (Gottwald et al 2021, n=180), and with hands of different sizes (Cowie et al 2022, n=229); as well as a third- person-perspective full body illusion (Cowie et al 2017, n=97), and a virtual hand illusion (Dewe et al 2021, n=197). We suggest that visuotactile information is used to maintain a sense of the bodily self in children from 4-5-years old, allowing them to embody fake hands and bodies which are spatially misaligned with their own. Further, in contrast to e.g. postural cues, visuotactile congruence contributes to both a sense of own-body position and a sense of body ownership. We argue that visuotactile information operates separately from both unisensory 'visual capture' and multisensory visuomotor congruence. We suggest that children are more sensitive than adults to the form of stimulation given: in the context of sparse visuotactile information, they are less willing than adults to 'reject' a viewed body part as their own. Finally, we show that despite its importance, at present visuotactile congruence cannot be well replicated in fully virtual setups. We conclude with some suggested future directions for this area.

Talk 4 - Development of audio-haptic integration for the perception of object size

Meike Scheller 1, Michael J. Proulx 1, Katrin Petrini 1

1 University of Bath

During childhood and adolescence, the perceptual systems develop in close interaction with each other and as our bodies grow, the interplay between the senses changes. Previous research showed that when young children are presented with multiple cues simultaneously, they employ a strategy whereby they either switch between the cues or show sensory dominance. Only later in childhood do they show markers of adult-like, reliability-weighted integration. However, while the majority of previous studies tested the integration with vision, the interplay between hearing and touch received comparingly little attention. This information, however, is vital, especially in instances where visual information is impaired or absent. Using an audio-haptic size discrimination task, we traced the degree of integration of sound and touch information across childhood and adult development (N = 92). Our results showed that the benefit obtained from having two cues available increases around adolescence, becoming more adult-like between 13 and 16 years of age. Before that, discrimination performance suggests that children focus predominantly on one of the cues, or switch between the two. Lastly, the ability to detect cue congruency developed throughout adolescence, and did not reach adult-like levels until 17 years of age. Overall, this suggests that, compared to other sensory systems, the integration of touch and hearing takes the longest to mature. To what extent the late maturation may be a reflection of the active or multi-cue nature of touch (involving tactile and proprioceptive cues), or the perceptual feature that the information codes for, remains to be determined.

SYMPOSIUM #8
JUNE 30 | 10.30-12 PM
EINSTEIN ROOM

Resolving old debates, posing new questions: Factors influencing the development of multisensory processes in typical and atypical populations

Paul Matusz*, Mark Wallace, Milene Bonte, Marko Nardini

***Main organiser**

Multisensory processing is one of the most fundamental neurocognitive capacities, creating scaffolding for healthy development and shaping skill acquisition. Recently, evidence has been converging to resolve the old debates, for example, as to “when” multisensory processes develop. We now know that aspects of multisensory processing develop surprisingly late, and that atypical development often includes multisensory issues. However, major questions remain open, as to “how”: What factors influence this late development in both typical and atypical populations? To what extent these developing multisensory processes shape the learning of various everyday skills? Answering these questions would help better bridge multisensory research and traditional theories of brain- cognitive development, and substantially improve both teaching and clinical practice. Marko Nardini presents a series of studies using audiovisual localisation tasks to reveal that the weaker multisensory integration abilities in children (10-12 year old) stem from internal biases regarding the single versus multiple sources of the cross-modal signals. Paul Matusz builds on these findings by presenting how adult-like multisensory enhancement of visual attentional capture does not occur until 9-10 years and points to the engagement of different brain networks as a potential mechanism. Simultaneously, he discusses how age group-specific EEG patterns are selectively linked to early educational competences. Milene Bonte enriches these education-related findings, by using converging behavioural, EEG and fMRI evidence to propose a neurocognitive model of audiovisual script association learning, and how atypicalities in the underlying processes may predict future reading problems. Finally, Mark Wallace provides an integrative, neurodiversity perspective by showing how enlargement of the temporal binding window is shared across autism and dyslexia but predicts selective and distinctive difficulties in those conditions. We finish the symposium by discussing the questions opened by these findings, i.e., how malleability of multisensory processes can be used as a tool to better understand and treat developmental/learning disorders.

Talk 1 - Learning to combine sensory signals: the role of biases and calibration in childhood

Marko Nardini 1
1 Durham University

An interesting but poorly understood finding in multisensory development is that, unlike adults, children under 10-12 years tend not to gain precision in multisensory perceptual judgments vs when using the best single cue alone. Because children's unisensory judgments tend already to be imprecise, this population would especially benefit from an integration strategy, but seem not to. Why not? Here, we address a key potential barrier to integration: the possibility that signals coming from a common source (which an ideal observer would integrate) are experienced as having a bias, or offset (which an ideal observer might determine to come from different sources, and so not integrate). Because part of the challenge for a developing perceptual system is to learn cue mappings, it is easy to suppose that these mappings could at times be systematically biased during incomplete development and learning. Yet, few studies have checked for or measured any such naturally-occuring biases or related them to combination performance. Over a series of studies with children and adults making spatial judgments
using visual and auditory cues, we show that (1) biases between cues can be substantial, especially in childhood; (2) the magnitude of individuals' biases can predict their combination behaviour in the expected direction; (3) combination is more effective after training that can improve single-cue biases. We conclude that biases in single cues are a contributing factor to limited cue integration in childhood and discuss implications for training – during typical and atypical perceptual development, and for lifelong learning of new perceptual skills.

Talk 2 - Development of multisensory attention processes across primary education and their role in shaping early educational achievement

Paul Matusz 1,2
1 University of Applied Sciences and Arts of Western Switzerland, 2 The SENSE Research and Innovation Center

Visual attention is known to shape learning. Yet, despite multisensory nature of classrooms, it remains unclear how developing multisensory (audiovisual, AV) processes influence children's attention and educational achievement. We investigated how AV simultaneity detection and top-down, goal-based visual attention develop during primary schooling and shape reading and basic maths. We recorded EEG from 1st-, 3rd- and 5th-graders (5-, 7- and 9-year-olds, respectively) and adults, while they searched for colour-defined "diamond" targets, preceded by colour and colour-sound distractors. Spatial-cueing effects and N2pc component (analysed canonically and using electrical neuroimaging [EN]) served as behavioural and EEG markers of visual-attention capture. Already 3rd-graders showed adult-like top- down visual attention, but not even 5th-graders showed adult-like AV enhancement of attentional capture. In adults, EN revealed stable lateralised EEG activity patterns in the N2pc time-window, modulated by both AV and visual processes. In children, adult-like N2pc's were absent. EN analyses revealed that 3rd-graders activated adult-like EEG patterns in the N2pc time- window, but AV attention modulated different EEG patterns than those in adults. Analyses of age group-specific EEG patterns revealed visual and AV attentional modulations in N2pc time- window in both 3rd- and 5th- graders. Crucially, these age-specific EEG patterns (but not traditional markers) were linked with standardised educational skills, with age determining the sign and type of relationships. These findings underlie the importance of age in determining if attention utilises multisensory processes to support early educational success, and of use of sensitive, well-understood methods in revealing the role of multisensory processing in shaping early skills.

Talk 3 - Neurobehavioral (a)typicalities in letter-sound association learning, a relevant predictor of individual differences in reading?

Milene Bonte 1
1 University of Maastricht

The formation of efficient associations between visual and spoken language representations forms a fundamental step in the acquisition of reading. Although we have a fairly good understanding of how our brain processes already learnt associations and how this may differ in individuals with reading problems (dyslexia), we know very little about the actual behavioral and neural changes that occur during the learning process itself. In this talk I will discuss behavioral, EEti and fMRI data of children and adults obtained with different learning paradigms including text-based recalibration and audiovisual script learning. Together these data provide first evidence for diverging letter-sound learning processes in individuals with/without dyslexia as well as possible modulatory effects of perceptual (phonological similarity) and general cognitive (attention skills) factors. Building on these data, I will propose a model of individual differences in neurobehavioral changes during letter-sound association learning and will discuss why a better understanding of these differences in young children may be crucial for predicting who will learn to read fluently and who will need extra support to prevent reading problems.

Talk 4 - Multisensory contributions to neurodiversity: A developmental perspective

Mark T. Wallace 1
1 Vanderbilt University

Neurodiversity is an increasingly used term that is meant to capture the differences in brain structure and function that underlie individual differences in behavior, perception and cognition. Although used in a number of contexts, it is often used to describe autistic and dyslexic individuals, representing two forms of neurodevelopmental divergence. Our lab has characterized various facets of sensory and multisensory function in these populations, providing a valuable view into how changes in (multi)sensory capacities may relate to higher-order perceptual and cognitive abilities. The talk will review evidence for shared differences in multisensory temporal function in autism and dyslexia, with a core finding of an enlarged temporal binding window. However, and despite this common characteristic (and some degree of co-occurrence of dyslexia in autism), the two manifest in very different ways, with audiovisual temporal function being strongly linked to poor reading ability in dyslexia but to weaker social communication abilities in autism. I will speculate on how shared alterations to a common multisensory mechanism may manifest in such divergent phenotypic profiles, and how development may be a key moderator of how these differences emerge.

TALK SESSION #1
JUNE 27 | 16-17.30 PM
EINSTEIN ROOM

Brain adaptation to sensory deprivation

Talk 1 - Computational hierarchy for tactile reading and speech processing in the occipital cortex of blind people

Matuszewski Jacek 1,2,3, Bola Łukasz 4, Collignon Olivier 1,2,5, Marchewka Artur 3

1 Institute of Research in Psychology (IPSY), University of Louvain (Belgium), 2 Institute of Research in Neuroscience (IoNS), University of Louvain (Belgium), 3Nencki Institute of Experimental Biology, Polish Academy of Sciences (Poland), 4 Institute of Psychology, Polish Academy of Sciences (Poland), 5 The Sense Innovation and Research Center (Switzerland)

The blind visual cortex responds to touch or sounds in a functionally specific fashion. However, the degree of retained cortical functionality is still debated. Here, we investigate the roles of the “visual” cortex of early blind and sighted people in reading and speech processing. Using fMRI we identified neuronal responses to words, pseudowords, and low-level sensory stimuli during reading and speech processing. While the blind early visual cortex (EVC) responded to linguistic and simple sensory stimuli, activity in the visual word form area (VWFA), was specific to linguistic information across modalities. Similar reading-specific activity in VWFA was observed in sighted subjects but only for visual reading and not for speech. Next, we used chronometric transcranial magnetic (chTMS) stimulation to causally trace the information flow between EVC and VWFA. We disrupted neuronal processing in the EVC and VWFA during reading and speech processing with 20Hz paired-pulse TMS in three distinct time windows (TW) from 60 to 260 ms after stimuli presentation. During reading, the involvement of the blind EVC precedes the one of VWFA but it also persists in the later TWs suggesting potential feedback mechanisms. These chTMS effects were remarkably similar to those of sighted controls who were reading printed material visually. TMS did not interfere with speech processing in any group at any temporal windows. These results suggest that the computational hierarchy of the visual cortex for reading is preserved in blind people reading Braille, and to a lower extent for speech processing.

Talk 2 - Visual experience is necessary for dissociation of responses to faces versus language in the fusiform

Saccone Elizabeth 1, Lnu Akshi 1, Kim Judy 1, Tian Mengyu 1, Kanwisher Nancy 1, Bedny Marina 1

1 Department of Psychological and Brain Sciences, Johns Hopkins University (United States)

Previous studies have found responses to both perceptual (e.g., face touching) and high-level (e.g., language) tasks in the visual cortices of blind people. Do these functions occupy the same or different parts of visual cortex? Congenitally blind (n=11) and sighted control (n=15) participants performed both face perception and language fMRI experiments. We tested functional specialization for faces and language in the ventral occipito-temporal cortex (VOTC) using individual-subject analyses. Blind participants touched 3D-printed models of faces and scenes and performed a 1-back task. The same participants performed reading and spoken language tasks with tactile Braille words, Braille consonant strings and tactile control shapes, spoken words and audio control (backwards speech). Sighted blindfolded controls (n=15) performed an analogous language task but with visual words and viewed line-drawings of faces and objects. In the blind group, we replicate the previously observed left-lateralized responses to tactile faces in lateral VOTC, at or near the classic fusiform face area (FFA). However, for blind people, face-responsive voxels (faces>scenes) in the VOTC also responded to written and spoken language (Braille/spoken words>control). By contrast the sighted showed a clear functional dissociation between VOTC responses to language and faces, whereby face responsive voxels did not show higher activity for written/spoken words than control conditions. Visual experience is not required for responses to tactile faces in left VOTC but is necessary for specialization for faces as opposed to language. An intriguing possibly is that connectivity to communication-relevant language regions together with visual experience leads to face/language dissociation in VOTC of sighted.

Talk 3 - Effects of experience on development of visual cortex: comparing sighted infants to blind and sighted

Tian Mengyu 1, Xiao Xiang 2, Hu Huiging 3, Cusack Rhodri 4, Bedny Marina 5

1 Beijing Normal Zhuhai (China), 2 National Institute on Drug Abuse, National Institutes of Health (United States), 3 Trinity College Institute of Neuroscience and School of Psychology (Ireland), 4 Trinity College Dublin (Ireland), 5 Johns Hopkins University (United States)

Comparing adults with different sensory histories (blind vs. sighted) has uncovered effects of experience on human brain development. However, little is known about the developmental origins of experience-based plasticity in humans, since until recently all research has been done with adults. A key outstanding question is whether experience plays an instructive role in establishing functional signatures observed in typical development. Alternatively, the typical functional pattern might be present innately and reorganized by atypical sensory experience e.g., blindness. Here we dissociate instructive and reorganizing effects of experience by comparing the 'starting state' of visual cortex functional connectivity in two large cohorts of sighted infants (average age of 2 weeks, n=327, n=475 from dHCP) to those of blind (n=30) and blindfolded sighted (n=50) adults. Remarkably, we find that in secondary visual cortices the connectivity profile of infants resembles that of blind more than sighted adults: stronger connectivity with prefrontal than non-visual sensory networks (i.e., auditory, somatosensory). Visual experience appears to couple of visual cortex with other sensory-motor networks and de-couple visual from prefrontal cortices. Primary visual cortex (V1) shows a mixture of instructive and reorganizing effects, starting with equal frontal and sensory-motor connectivity at birth and diverging in opposite directions in sighted and blind adults. Finally, lateralization of occipital connectivity appears to be driven by blindness-related reorganization. These results dissociate instructive and reorganizing effect of experience on functional connectivity of human cortex and open new avenues for investigating the developmental origins of visual cortex function in humans.

Talk 4 - Altered grid-like coding in early blind people during imagined navigation

Sigismondi Federica 1,2, Xu Yangwen 2,3, Silvestri Mattia 2, Bottini Roberto 1,2
1 University of Trento (Italy), 2 Center for Mind/Brain Sciences (Italy), 3 Max Planck Institute for Human Cognitive and Brain Sciences (Germany)

Spatial Navigation in humans mostly relies on vision. However, the impact of early visual deprivation on the recruitment of the Human Navigation Network (HNN) and the creation of cognitive maps sustained by grid-cells in the Entorhinal Cortex (EC), is still yet unknown. Here, we tested blindfolded early blind (EB, 19) and sighted controls (SC, 19) individuals in both an fMRI imagined navigation and real-world navigation tasks. During the fMRI experiment participants were asked to imagine navigating within a clock-like environment going from one number to the other following auditory instructions (e.g., you are at 4 – go to 8). In the real-world navigation task, instead, blindfolded participants walked through different paths and were asked to estimate their distance and orientation compared to their starting point. Univariate analysis revealed that the two groups equally activated the HNN during clock navigation, demonstrating the resilience of this network to visual deprivation. However, hexadirectional coding analyses showed different neural geometries in the entorhinal cortex: six-fold (60˚) rotational symmetry, characteristic of grid-like coding, in SC and 4-Fold symmetry (90˚) in EB. Interestingly, higher parietal cortex activity during navigation, in the EB, was correlated with higher magnitude of 4-Fold symmetry as well as real-word navigation performance. Moreover, contrary to SC, EB's cognitive map was anchored to the main axis of the clock environment. In sum, early visual deprivation alters the neural geometry of entorhinal cognitive maps. Our results further suggest that this alteration may derive from EB's higher reliance on an egocentric reference frame during navigation.

Talk 5 - Activation of human visual area V6 during egocentric navigation with and without visual experience

Aggius Vella Elena 1, Chebat Daniel-Robert 2, Maidenbaum Shachar 3, Amedi Amir 1
1 Reichman University (Israel), 2 Ariel University (Israel), 3 Ben-Gurion University of the Negev (Israel)

Introduction: V6 is a retinotopic area located in the dorsal visual stream that integrates eye movements with retinal and visuo-motor signal. Despite the known involvement of V6 in visual motion, it is still unknown whether it is involved in navigation and how sensory experiences shape its functional properties. We explored the involvement of V6 in egocentric navigation in sighted and in congenitally blind (CB) participants navigating via an in-house distance-to-sound sensory substitution device (SSD), the EyeCane.
Method: We performed two fMRI experiments on two independent datasets. In the first experiment, CB and sighted participants navigated the same mazes. The sighted performed the mazes via vision, while the CB via audition. The CB performed the mazes before and after a training session using the EyeCane SSD. In a second experiment a group of sighted people performed a motor topography task.
Results: Results show that right V6 (rhV6) is selectively involved in egocentric navigation independently by the sensory modality used. Indeed, after training rhV6 of CB is selectively recruited for auditory navigation like rhV6 of the sighted. Moreover, we found activation for body movement in area V6, that can putatively contribute to its involvement in egocentric navigation. Taken together, our findings suggest that area rhV6 is a unique hub that transforms spatially relevant sensory information into an egocentric representation for navigation. While vision is clearly the dominant modality, rhV6 is in fact a supramodal area that can develop its selectivity for navigation in the absence of visual experience during the critical period.

Talk 6 - Audiovisual Speech Integration in Cochlear Implant Users

Butler Blake 1, Salagovic Cailey 1, Stevenson Ryan 1
1 University of Western Ontario (Canada)

Speech is a rich multisensory stimulus that combines a dynamic stream of auditory information with visual cues arising from articulatory movements. In many situations, speech is fully intelligible based on auditory cues; however, the addition of visual speech cues results in significant gains in intelligibility when auditory cues are poorly resolved. The inverse effectiveness of visual cues has been well documented for speech presented in acoustic noise; however, less is known about the relative role of visual speech signals when auditory cues are degraded in other ways. Cochlear implants are a neural prosthesis capable of restoring a representation of sound to individuals with profound hearing loss. When provided very early in development, children with cochlear implants often go on to score similarly to their typically-hearing peers on tests of speech intelligibility by the time they are school-aged. However, the sound signal provided by a cochlear implant is of significantly poorer resolution than that provided by the intact cochlea. Here, we present data from two experiments that examined how auditory and visual speech cues affect perception in cochlear implant users compared to typically-hearing listeners. In the first, we examine how discordant cues are combined to generate illusory syllables (the McGurk effect) and discuss how similarities in behavioural performance may mask groupwise difference in thresholds for integration and sensory noise. In the second, we compare how these groups of listeners respond to temporal asynchrony between auditory and visual speech cues and discuss how differential weighting across modalities might affect listening strategies.

TALK SESSION #2
JUNE 28 | 8.30-10 AM
EINSTEIN ROOM

Multisensory development in humans and other animals

Talk 1 - The Solution of the Multisensory Cocktail Party Problem (MCPP) Emerges Gradually in Development

Lewkowicz David 1

1 Yale University (United States)

The MCPP arises whenever multiple interlocutors interact with one another socially. During such interactions, interlocutors are confronted with multiple sets of audiovisual attributes belonging to the other interlocutors. To solve the MCPP and communicate successfully, interlocutors must correctly integrate sets of auditory and visual attributes belonging to different talkers and segregate them into distinct entities. To understand the developmental aspects of the MCPP, we devised a multiple talker paradigm to investigate audiovisual integration and segregation in young children and adults. Subjects see multiple talking faces articulating temporally jittered monologues and hear a monologue that is temporally synchronized with one of the talking faces and sometimes also corresponds in terms of identity and/or semantic cues. Using an eye tracker, we measure selective attention to the faces, eyes, and mouths as a proxy for integration and segregation. Findings indicate that subjects prefer the synchronized faces, that this preference increases with development, that subjects attend more to the mouth than eyes when talking faces are audiovisually desynchronized, and that audiovisual synchrony plays an outsize role compared to identity and semantic cues. Overall, we interpret the developmental emergence of a preference for synchronized/concordant talking faces as reflecting (a) our nearly exclusive exposure to synchronized talking faces and the consequent growth of the multisensory unity assumption, (b) the growth of multisensory integration ability, and (c) the growth of multisensory perceptual segregation ability. Together, these findings demonstrate that the challenges of the MCPP become more tractable as development progresses and as children acquire multisensory processing skills.

Talk 2 - Modulation of somatosensory processing by visual and auditory moving stimuli in newborns

Orioli Giulia 1, Cruse Damian 1, Bremner Andrew 1
1 University of Birmingham (United Kingdom)

Adults are able to precisely predict when and where they will feel a touch following auditory and visual motion towards their body. It is likely that this ability plays an important role in daily life, and in supporting our representation of events taking place in the space around us. Surprisingly, little is known about how this ability develops during infancy and childhood. Recently, we showed that a sample of at 4-month-old infants' somatosensory evoked potentials (SEPs) were modulated according to whether the somatosensory stimulus was preceded by approaching vs receding visual motion. Such an early appearance of this differentiated response raised the question of whether this crossmodal sensory capacity is established even earlier in development. We have begun to investigate this by exploring newborns' (13- to 40-days-old) SEP responses to touches preceded by approaching vs receding visual or auditory motion. Data collection is currently in progress (expected sample size, N = 20), but thus far we found clearer evidence of a modulation of the SEP following auditory (n = 10) rather than visual motion (n = 7). There appears to be an enhanced somatosensory response to a touch (300-900 ms post stimulus onset) when preceded by a sound increasing vs decreasing in amplitude. Evidence of a differentiated response to touches following approaching vs receding auditory or visual stimuli (or both) would indicate that from very early in postnatal development humans are sensitive to the relationship between auditory and/or visual stimuli in the extrapersonal space and tactile stimuli on the body.

Talk 3 - Age-Related Changes in Multisensory Processing: Auditory-Visual Superadditivity and the Preservation of Audiovisual Speech

Dias James 1, Rumschlag Jeffrey 1, Mcclaskey Carolyn 1, Harris Kelly 1
1 Medical University of South Carolina (United States)

Despite age-related deficits in heard and seen speech perception, older adults can perform as well as younger adults when identifying audiovisual speech, even in noisy listening conditions. We recently found that this preservation of audiovisual (AV) speech can be accounted for by an age-related increase in auditory-visual superadditivity (SA) – the multisensory benefit above the combined auditory-only (AO) and visual-only (lipreading, VO) performance [SA=AV-(AO+VO)]. This behavioral evidence suggests that older adults rely more on multisensory integration to disambiguate the degraded speech information available from auditory and visual sources. To test this hypothesis, we recorded speech-evoked potentials (SEPs) elicited by consonant-vowel syllables in a subset of the same group of younger and older adults. Syllables were presented AO, VO, or AV. SEPs were source-constrained to auditory and visual cortex and the temporoparietal junction (supramarginal gyrus and planum temporal), a cortical area important for the cross-sensory integration of speech information. All participants had normal or corrected-to-normal sight. Younger adults had normal hearing. Hearing varied in older adults from normal hearing to mild-to-moderate sensorineural hearing loss. The electrophysiological data suggest that older adults exhibit a more robust superadditive benefit than younger adults, consistent with past findings. Importantly, the superadditive benefit measured in the temporoparietal junction predicted the superadditive benefit of older adults identifying audiovisual speech in noise. The results support our hypothesis that older adults rely more on multisensory integration to identify audiovisual speech and suggest that age-related neuroplastic changes at the cortical level can help compensate for age-related unisensory deficits.

Talk 4 - The inverse effectiveness of maternal odor on rapid face categorization in the 4-month-old infant brain

Kiseleva Anna 1, Rekow Diane 1,2, Schaal Benoist 1, Leleu Arnaud 1
1 Development of Olfactory Communication & Cognition Lab (France), 2 Biological Psychology and Neuropsychology, University of Hamburg (Germany)

To navigate their complex multisensory environment, infants bind together information from different sensory modalities. Such multisensory elaboration is particularly observed when unisensory inputs are not fully effective on their own, a principle known as inverse effectiveness. Given that this principle was mainly demonstrated using audiovisual stimulations, here we aim to determine whether it also applies to olfactory-visual interactions. We build on previous evidence that maternal odor enhances a face-selective neural response at 4 months, and investigate whether such odor influence depends on the effectiveness of face categorization for the visual system. Scalp EEG was recorded in 2 groups of 4-month-olds while they watched 6-Hz streams of pictures with faces inserted every 6th picture to tag a face-selective response at 1 Hz. In group 1, we used variable natural images, while images were edited to reduce variability and make face categorization less demanding in group 2. During visual stimulation, infants were alternatively exposed to a T-shirt worn by their mother or to a control T-shirt. For both groups, we found an occipitotemporal face-selective neural response, but with a significantly larger amplitude for the edited images, reflecting more efficient categorization. Importantly, maternal odor enhances the selective response to natural but not to edited face images, suggesting that maternal odor improves face categorization only when it is demanding for the 4-month-old visual system. Overall, this study indicates that the principle of inverse effectiveness applies to different senses during perceptual development, including the sense of smell.

Talk 5 - Cooling Visual Cortex Differentially Impacts Multisensory Responses Across Regions of Ferret Auditory Cortex

Norris Rebecca 1, Town Stephen 1, Wood Katherine 2, Bizley Jennifer 1
1 University College, London (United Kingdom), 2 University of Pennsylvania (United States)

Multisensory integration is evident across many contexts and species. In the ferret, some neurons in auditory cortex (AC) respond to visual stimuli, and others show modulation of auditory responses by visual stimuli. AC receives input from several potential sources of visual information. Here, we investigated the role of a sub-region of visual cortex (Suprasylvian cortex, SSY, and adjacent area 21) in multisensory integration. SSY and 21 send dense projections to AC, particularly to the anterior ectosylvian gyrus (AEG). To assess the functional relevance of these connections, we recorded AC neurons while presenting auditory, visual and audiovisual stimuli before, during and after transient inactivation of SSY via cortical cooling in ferrets under ketamine-medetomidine anaesthesia. Analysis was restricted to stimulus responsive units exhibiting firing rate recovery following cooling. 279 units met our criteria, of which 54 (19%) responded to light, 163 (58%) responded to broadband noise, and 62 (22%) responded to both sound and light. Cooling SSY impacted 39% (21/54) of visual units, and 51% (32/63) of multisensory units, most of which exhibited decreased firing. However, we recorded 7/279 units in which responses emerged or increased during cooling. We found the greatest impact of cooling on visual responses in posterior ectosylvian gyrus, rather than AEG. We found visual units across all cortical layers, with infragranular layers exhibiting the greatest proportion of visual units. These findings support a functional role for both excitatory and inhibitory effects of visual cortex on audiovisual integration in AC, while also implicating the involvement of additional pathways.

Talk 6 - Temporal Course of Visual Modulation Revealed by Local Field Potentials in Cat Primary Auditory Cortex

Bao Xiaohan 1, Lomber Stephen 2

1 Integrated Program in Neuroscience, Faculty of Medicine, McGill University (Canada), 2 Department of Physiology, Faculty of Medicine, McGill University (Canada)

Understanding visual modulation of auditory processing in hearing subjects is an important step to reveal the mechanisms of the cross-modal plasticity in deaf individuals and to discover effective interventions for preserving multisensory functions after auditory restoration. Previously, we have studied the visual modulation of auditory evoked potentials (AEPs) in cats and found that a click-evoked negative peak component at <100-ms latency was modulated by a preceding flash depending on the flash-to-click delay. To follow up on this finding, we chronically implanted two 32-channel electrode matrices for extracellular recording in primary auditory cortex (A1) of two additional adult cats. During the recording, the cats were presented with audiovisual stimuli similar to the previous AEP study, using checkerboard instead of flash, while performing a fixation task. Local field potentials (LFPs) were extracted from the scores of the first five PCA components as well as each individual channel. Our preliminary analysis show that visual modulation of click-evoked LFPs was again affected by the delay between checkerboard flipping and click onset. The latency of the affected LFPs varied across recording channels and PCA components, as well as the pattern of delay dependency, which suggested A1 may have microcircuits for weak but versatile cross-modal functionality. Illuminated by the phase reset hypothesis (Lakatos, 2007), further data analysis will be performed to investigate the spectral properties of the delay dependency. Our findings are encouraging for future studies on characterizing visual modulation of deaf auditory cortex using cat as an animal model.

TALK SESSION #3
JUNE 29 | 8.30-10 AM
EINSTEIN ROOM

Audio-visual and visuo-tactile multisensory integration

Talk 1 - Dynamic re-weighting in audiovisual integration

Blokland Dominique 1, Alais David 2, Van Der Stoep Nathan 1
1 Utrecht University (Netherlands), 2 The University of Sidney (Australia)

In recent years our understanding of multisensory processing has advanced and rigid combination rules have given way to flexible, Bayesian-inspired models that “weigh” the senses based on their reliability to optimise perception. Although this intuitive idea of flexibly weighing sensory inputs accounts well for simple forms of multisensory perception in lab-based experiments, real-world conditions are dynamic and variable. Truly understanding how humans flexibly adapt to their environment requires a continuous method to measure multisensory integration. Recent studies have started exploring these dynamics and showed that the reliability of the sensory past is considered during multisensory integration in the present. We pioneered an all-new continuous multisensory tracking method required to test, in real time, how the brain continually re-weights sensory inputs to understand our changing environment. We specifically investigated how a sudden change in visual reliability from high to low and vice versa, impacted dynamic cue weighting. We measured the perceived spatial location of randomly moving virtual auditory, visual, and audiovisual targets at 60Hz by letting participants track these targets with their mouse cursor. Visual reliability was randomly changed from high to low and vice versa. Participants’ real-time tracking performance, sensory weights, and prediction errors over time showed that observers adapted their sensory weights quickly, especially when visual information suddenly became highly reliable.

Talk 2 - Multisensory integration operates on correlated input from unimodal transient channels

Parise Cesare 1, Ernst Marc 2

1 Department of Psychology, University of Liverpool (United Kingdom), 2 Department of Psychology, University of Ulm (Germany)

Audiovisual information reaches the brain via both sustained and transient input channels, representing signals' intensity over time or changes thereof, respectively. To date, it is unclear to what extent transient and sustained input channels contribute to the combined percept obtained through multisensory integration. Based on the results of two novel psychophysical experiments, here we demonstrate the importance of the transient (instead of the sustained) channel for the integration of audiovisual signals. To account for the present results, we developed a biologically-inspired, general-purpose model for multisensory integration, the Multisensory Correlation Detectors, which combines correlated input from unimodal transient channels. Besides accounting for the results of our psychophysical experiments, this model could quantitatively replicate several recent findings in multisensory research, as tested against a large collection of published datasets. In particular, the model could simultaneously account for the perceived timing of audiovisual events, multisensory facilitation in detection tasks, causality judgments, and optimal integration. All-in-all, this study demonstrates that several phenomena in multisensory research that were previously considered unrelated, all stem from the integration of correlated input from unimodal transient channels.

Talk 3 - Shape detection beyond the visual field using a visual-to-auditory sensory augmentation device

Shvadron Shira 1, Snir Adi 1, Maimon Amber 1, Yizhar Or 1, Harel Sapir 1, Poradosu Keinan 1, Amedi Amir 1

1 Reichman University (Israel)

Current advancements in both technology and science allow us to manipulate our sensory modalities in new and unexpected ways. In the present study, we explore the potential of expanding what we perceive through our natural senses by utilizing a visual- to-auditory sensory substitution device (SSD), the EyeMusic, an algorithm that converts images to sound. In this study, we aimed to use the EyeMusic for the blind areas of sighted individuals. We use it in this initial proof-of-concept study to test the ability of sighted subjects to combine visual information with surrounding auditory sonification representing visual information. Participants in this study were tasked with recognizing and adequately placing the stimuli, using sound to represent the areas outside the standard human visual field. As such, the participants were asked to report shapes' identities as well as their spatial orientation, requiring combined visual (90° frontal) and auditory input (the remaining 270°) for the successful performance of the task. We found that participants were successful at a highly above chance level after a brief 1-h- long session of online training and one on-site training session of an average of 20 min. They could even draw a 2D representation of this image in some cases. Participants could also generalize, recognizing new shapes they were not explicitly trained on. Our findings provide an initial proof of concept indicating that sensory augmentation devices and techniques can potentially be used in combination with natural sensory information in order to expand the natural fields of sensory perception.

Talk 4 - Functional specificity of auditory inputs to the visual cortex

Egea Weiss Alexander 1, Domanski Aleksander 1, Viduolyte Aiste 1, Marianelli Elsa 1, Cano-Ferrer Xavier 1, Konstantinou George 1, Iacaruso Maria Florencia 1
1 The Francis Crick Institute (United Kingdom)

The brain continuously receives a wealth of sensory information, and uses this information to guide behaviour. However, the process by which different sensory streams are integrated to form a unified percept remains poorly understood. Cortical regions dedicated to a specific sensory modality nonetheless receive input related to other modalities. The mouse auditory cortex sends numerous projections to the primary visual cortex and surrounding higher visual areas. These inputs may be crucial to the integration and binding of auditory and visual signals. Yet the exact nature of the auditory information carried by these inputs, and how they are organised within the visual cortices remains undetermined. We characterised the functional response properties of auditory cortex axonal projections to the mouse visual cortex using two-photon calcium imaging. We found that while all visual cortical areas studied receive axons tuned to a wide range of sound frequencies and sound source locations, the encoding of these features is not uniformly distributed across target regions. In particular, sound frequency varies along the anteriorposterior axes of the visual cortex. Furthermore, while information about lateral sound locations is conveyed widely across the visual cortex, information about sounds originating from the centre of the visual field is excluded from the primary visual cortex and most prominently conveyed to the rostrolateral visual cortex. Together, these results suggest that segregated auditory input to the visual cortex might lead to distinct multisensory representations across cortical areas.

Talk 5 - Aligned motion-direction information for touch and vision in the human brain

Shahzad Iqra 1, Battal Ceren 1, Cerpelloni Filippo 1,2, Van Audenhaege Alice 1, Mouraux André 1, Collignon Olivier 1,3
1 Insitute of Neuroscience (IoNS) and Institute for Research in Psychological Sciences (IPSY), Université Catholique de Louvain (Belgium), 2 Brain and cognition, Leuven Brain Institute, KU Leuven (Belgium), 3 HES-SO Valais-Wallis, The Sense Innovation and Research Center (Switzerland)

Motion directions can be perceived through vision and touch. Do motion directions align across the senses somewhere in the brain, and if so, using which frame of reference? This is a non-trivial computational problem because vision and touch are initially coded using different spatial frames of reference, and because our limbs move constantly to adopt different postures. In the first experiment, we used fMRI to identify motion-selective regions in vision and touch. In addition to sensory specific motion selective regions, we observed that the middle occipito-temporal region (hMT+/V5) is motion selective across the senses. In another experiment, we delivered directional visual and tactile motion stimuli across different hand postures. Multivariate Pattern Analysis (MVPA) revealed that motion directions can be decoded in both vision and touch. Interestingly, tactile motion directions could be decoded in both body-centered and externally-centered coordinate systems. However, crossmodal decoding revealed that visual motion directions align with tactile directions only using an externally-centred coordinate system. Our results show that motion directions in vision and touch are aligned in hMT+/V5 relying on a common external frame of reference.

Talk 6 - Using Magnetoencephalography (MEG) to disentangle what happens when vision and touch converge: A multivariate source-level approach to the Rubber Hand Illusion

Hauser Maximilian 1, Coppi Sara 1, Lundqvist Daniel 1, Ehrsson H. Henrik 1
1 Karolinska Institutet (Sweden)

A well-known example of multisensory integration is the Rubber-Hand Illusion (RHI). The presentation of a visual and a tactile touch simultaneously, respectively, on the participant's hand and a rubber hand placed in an anatomically plausible orientation, can induce the feelings that the seen and felt touch arise from the same event and that the fake hand is perceived as the own. This phenomenon has been thoroughly investigated using functional magnetic resonance imaging (fMRI). However, this method often relies on univariate contrasts that constrain interpretability, and secondly, they do not provide information on the dynamics underlying the unisensory processes, the multisensory integration processes, and the emergence of illusion-related processes. To fill this knowledge gap, we conducted a large MEG study covering 7 different conditions across 2000 stimulation events in 46 participants. Using a whole-brain approach, we first reconstructed brain activity time-series for every single trial. We subsequently estimated the cross-validated Mahalanobis distance of these source-level time series in conjunction with representational similarity analysis to disentangle commonalities and differences across trials based on their belonging to a visual or tactile, a uni- or multisensory, a congruent or incongruent rubber hand placement, or whether they would result in the sensation of ownership. In this presentation, I will show a previously unattained temporospatial resolution of how the many processes involved in the RHI unfold in the brain. These results are visualized in videos for closer discussion of the spatiotemporal interactions between key-regions related to the rubber hand illusion and integration of bodily signals.

TALK SESSION #4
JUNE 30 | 8.30-10 AM
EINSTEIN ROOM

Impact of sensory experience on body and emotion representation

Talk 1 - Body perception and brain plasticity in blind and sighted individuals: from heartbeats to rubber hands

Blokland Radziun Dominika 1, Korczyk Maksymilian 2, Crucianelli Laura 1, Szwed Marcin 2, Ehrsson H. Henrik 1

1 Department of Neuroscience, Karolinska Institutet (Sweden), 2 Institute of Psychology, Jagiellonian University (Poland)

Visual input, together with touch, proprioception, interoception, and other sensory modalities, are thought to play an important role in the development and maintenance of multisensory awareness of one's own body. How does this sense of the own body arise in blind individuals, and what kind of compensatory plasticity processes are involved? Here we present a series of experiments that focused on this profoundly understudied topic – bodily awareness following blindness. We tested 36 blind individuals and 36 age and sexmatched sighted volunteers. In experiment 1, we showed that blind individuals have significantly higher accuracy in perceiving their heartbeat sighted individuals. In experiment 2, we provided a broader insight into tactile perception following blindness by studying both discriminative and affective touch plasticity in blind and sighted groups. In experiment 3, we re-examined a classic paradigm to study body ownership, somatic rubber hand illusion, in a largest to date sample of blind participants. We showed that blind individuals do not experience the somatic rubber hand illusion, which suggests that changes in multisensory integration of tactile and proprioceptive signals, possibly combined with more accurate interoception, may explain why blind individuals appear "immune" to the nonvisual version of the rubber hand illusion. Taken together, this series of experiments is the first attempt to systematically describe differences and similarities between blind and sighted individuals in bodily awareness and the functioning of the bodily senses, opening a new important line of research.

Talk 2 - Bodily representation of emotions in blind people

Lettieri Giada 1, Calce Roberta 1, Giraudet Eléonore 1, Collignon Olivier 1,2,3

1 Institute of Research in Psychology, & Institute of Neuroscience, Université Catholique de Louvain (Belgium), 2 HES-SO Valais-Wallis, The Sense Innovation and Research Center (Switzerland), 3 Center for Mind/Brain Sciences, University of Trento (Italy)

How do people represent their own and others' feelings in the body? Associations between affective experiences and the body can come from interoception, language or seeing changes in facial, postural and gestural behavior in people experiencing emotions (Levenson, 2003). To causally address how visual experience impacts how specific affective states are mapped onto discrete body parts, we developed a haptic procedure relying on a miniature human mannequin with a recording camera on top. Twenty early blind (9F) and 20 age-matched sighted (10F) had to indicate with their dominant index finger the parts of the body they felt activated when experiencing 15 positive and 15 negative emotions. A marker was applied to the finger to track their movement such that we obtained for each volunteer and emotion a map of activated regions. Despite important similarities between how blind and sighted people map emotional states onto the body, we also found reliable differences between blind and sighted individuals in the bodily maps of some selective emotions. Specifically, with euphoria, sighted reported bodily sensations in the face and stomach, while blind participants pointed to mouth region only. Similarly, for love, visually-deprived individuals do not report the stomach region, that is prominent in sighted. Overall, our results show that even though reliable bodily representation of emotion can be acquired without visual experience, blind individuals however seem to report more the head region for some specific emotions, suggesting that they retain the communicative and interpersonal role of bodily expressions, but rely less on interoceptive information.

Talk 3 - Abstract and sensory-specific coding of emotional information in the human brain

Cecchetti Luca 1, Handjaras Giacomo 1, Cappello Elisa 1, Setti Francesca 1, Bottari Davide 1, Leo Andrea 2, Diano Matteo 3, Bruno Valentina 3, Tinti Carla 3, Garbarini Francesca 3, Pietrini Pietro 1, Ricciardi Emiliano 1, Lettieri Giada 4

1 IMT School for Advanced Studies Lucca (Italy), 2 Department of Translational Research and Advanced Technologies in Medicine and Surgery, University of Pisa (Italy), 3 Department of Psychology, University of Turin (Italy), 4 IPSY, Université Catholique de Louvain (Belgium)

Emotions are perceptual experiences triggering evaluative processes. Therefore, it is no surprise that sight and hearing play a fundamental role in how humans capture affective information in the environment (e.g., an ominous noise) and emotional cues during social interactions (e.g., blushing). Notwithstanding decades of research, whether the brain encodes emotional instances using a sensory-specific code or in a more abstract manner is still unclear. Here, we aim to answer this question by measuring the association between emotional ratings collected during the audio-only (n=20), video-only (n=20) or audiovisual (n=22) presentation of a 54-minute movie and fMRI activity recorded in three independent samples of typically-developed individuals (n=30), as well as in congenitally blind (n=11) and congenitally deaf (n=9) participants. Results of a voxelwise encoding analysis reveal that emotions are mapped in a vast network encompassing medial prefrontal, orbitofrontal and bilateral superior temporal cortices. Within this network, the ventromedial prefrontal cortex (vmPFC) is recruited independently of the sensory modality and experience, whereas the engagement of the right posterior superior temporal cortex is independent from the modality but requires multisensory experience. Using pattern classification, we demonstrate that sensory experience, but not modality, is successfully decoded from the emotion network. Yet, neither experience nor modality can be decoded from vmPFC. This evidence suggests that the code the brain adopts to store emotional information is abstract in vmPFC and experience-dependent elsewhere. Lastly, using cross-decoding and valence ratings acquired in independent participants and across modality (n=62), we show this abstract code is representing the (un)pleasantness of experiences.

Talk 4 - Updating of internal models in Autism Spectrum Disorder

Noël Jean-Paul 1
1 New York University (United States)

Autism spectrum disorder (ASD) is characterized by a panoply of social, communicative, and sensory anomalies. As such, a central goal of computational psychiatry is to ascribe the heterogenous phenotypes observed in ASD to a limited set of canonical computations that may have gone awry in the disorder. In this talk, I will first demonstrate that well established anomalies in multisensory behavior in humans with ASD are derived from impairments in causal inference – the process of inferring a causal structure linking observed sensory signals to hidden world causes. Namely, we show that audio-visual integration is intact in ASD and in line with optimal models of cue combination, yet multisensory behavior is anomalous in ASD because this group operates under an inflexible internal model favoring integration over segregation. Paradoxically, during explicit reports of common cause across spatial or temporal disparities, individuals with ASD were less and not more likely to report common cause. Formal model fitting revealed differences in both the prior probability for common cause (p-common) and choice biases, which are dissociable in implicit but not explicit causal inference tasks. In the second part of the talk I will describe our recent efforts in translational neuroscience, indexing how internal models are updated in multiple mouse models of ASD. We develop a prior-dependent visual detection task for rodents and demonstrate that three different mouse models of ASD update their priors slowly – mimicking findings from humans. We record single units throughout the brain of these animals (55+ brain areas and 50k+ single cells). Encoding models and population analyses demonstrate the critical role of the hippocampus, and its impairments in ASD, in updating internal models.

Talk 5 - Motor metamodal? Perception and action without hands

Striem-Amit Ella 1
1 Georgetown University Medical Center (United States)

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 a series of fMRI experiments that show that parts of the association motor system are organized by the action performed 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. Drawing parallels across the insights gained from studies of blindness and deafness, I'll argue that studying handlessness allows tracking the brain hierarchies. Further, such research can open new avenues to use high-level action representations for motor rehabilitation.

Talk 6 - Gravity shapes the internal representation of 3D space

Morfoisse Theo 1, Herrera-Altamira Gabriela 1, Angelini Leonardo 2, Clement Gilles 3, Beraneck Mathieu 1, Mcintyre Joe 1,4, Tagliabue Michele 1

1 Integrative Neuroscience and Cognition Center (France), 2 HumanTech Institute, University of Applied Sciences Western Switzerland//HES-SO (Switzerland), 3 COMETE (France), 4 Tecnalia, San Sebastian (Spain)

Human visual 3D perception is flawed by distortions, which are influenced by gravitational vestibular signals. This could be due to a specific effect of gravity on visual objects perception or, alternatively, to a role of gravity in the modality-independent internal representation of 3D space, that the brain uses to interpret incoming sensory signals. To understand at which stage of the sensory processing does gravity act, we performed experiments where the subjects, using virtual reality and haptic technology, had to estimate the squareness of shapes with different spatial orientations. In three experiments, involving a total of 90 subjects, we compared 1) visual versus haptic 3D perception, 2) the effects of body orientation with respect to gravity and 3) during parabolic flights, the effect of microgravity on these two senses. The results show that: visual and haptic perceptual anisotropies reside in body-centered, and not gravity centered, planes; visual and haptic distortions are exactly in opposite directions; microgravity appears to affect both senses in a similar fashion with mainly an expansion of the depth perception. Overall, these results suggest that the gravity effect on object perceptions is not modality-specific, but it appears to affects our internal representation of 3D space. The role of gravity in object perception could be related to otolithic projections to the brain parietal cortex that is known to be involved in cross-modal processing and in spatial representation.

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#001 - Sensation transference from haptics to taste in drinking green tea: The effects of the lip thickness and weight of the glass
Atsunori Ariga, Fuka Ichimura, Kosuke Motoki, Koji Matsushita

#002 - Spatial ventriloquism: audiovisual integration adapts to context dynamically
Huanke Zeng, Lihan Chen

#003 - The Neural Dynamics of Tactile Pattern Integration
Shen Xu, Xiaolin Zhou, Lihan Chen

#004 - Dynamics of auditory categorization in the brain of sighted and blind
Siddharth Talwar, Stefania Mattioni, Eléonore Giraudet, Roberta Calce, Francesca Barbero, Olivier Collignon

#005 - Functional distinction of bimodal audiovisual neurons in the core and belt auditory areas
Yaser Merrikhi, Carina Sabourin, Sajad Jafari, Stephen Lomber

#006 - The Effects of Multiple Physical Factors on Creative Thinking, A Field Study
Sally Augustin, Cynthia Milota

#008 - The Contribution of Auditory Imagery to Sensorimotor Synchronization with Visual Rhythm
Fang Jiang, Benjamin Sreenan, Simon Whitton

#009 - Simple shape feature computation across modalities: Convergence and divergence between the ventral and dorsal visual streams
Shuang Tian, Yuankun Chen, Ze Fu , Xiaoying Wang, Yanchao Bi

#010 - Low-frequency activity as a privileged neural support of temporal integration in auditory vs. vibrotactile rhythm
Cédric Lenoir, Tomas Lenc, Sylvie Nozaradan

#011 - Suppressive bimodal neurons implement a nonlinear weighted average that resembles Bayesian multisensory combination
Vincent Billock, Adam Preston, Daniel Merfeld, M. Alex Meredith

#012 - Dissociable neuronal mechanism for different crossmodal correspondence effects
Carina Jaap, Michael Rose

#013 - Examining the Representation of Peripersonal Space in Adults with Fibromyalgia
Flavia Cardini, Jennifer Todd, Michael Lee, Jane Aspell

#014 - Effects of sound stimulus length and attributes on sound localization during self-motion perception
Masahiro Yamataka

#015 - Multisensory interactions between nociception and vision through the looking glass
Avgustina Kuzminova, Valéry Legrain, Lieve Filbrich

POSTER LIST
SESSION 1

#016 - The Impact of Premature Birth on Multisensory Processes in Very Preterm Schoolchildren
Marion Décaillet, Solange Denervaud, Laureline Besuchet, Cléo Huguenin-Virchaux, Céline Fischer, Micah Murray, Juliane Schneider

#017 - Increases in pre-stimulus theta oscillations precede successful encoding of crossmodal associations
Jan Ostrowski, Michael Rose

#018 - Memory formation of sequence-specific crossmodal associations is facilitated by dynamic changes in wide-spread alpha/beta power differences
Marike Christiane Maack, Jan Ostrowski, Michael Rose

#019 - Zooming on the spectrum: exploring the relationship between autistic traits, sensory sensitivity and Zoom-fatigue
Thijs Van Laarhoven, Sara Bögels, Marc Swerts, Jean Vroomen

#021 - Sniff or Not Sniff, That Is A Question for Egocentric Odor Localization
Kun Liang, Lihan Chen

#022 - Exploring the effect of ASMR on biomarkers and interpersonal space
Lovell Jones, Matt Bristow, Jane Aspell, Flavia Cardini

#023 - Surprising new insights on the effects of multisensory distraction on developing working memory
Nora Turoman, Elodie Walter, Anae Motz, Evie Vergauwe

#024 - Back to the past: the impact of illusory ownership of a child-like body on childhood memories
Utkarsh Gupta, Peter Bright, Sarah Coyle, Gwynnevere Suter, Eray Ertuğrul, Alex Clarke, Jane Aspell

#026 - Investigation of the effect of distractors on localization abilities with a visual-to-auditory substitution device
Camille Bordeau, Florian Scalvini, Cyrille Migniot, Julien Dubois, Maxime Ambard

#027 - Comparing the McGurk effect across Finnish and Japanese talkers and listeners
Kaisa Tiippana, Yuta Ujiie, Tarja Peromaa, Koshke Takahashi

#028 - A novel system to evaluate audio-spatial memory skills: the Audio-Corsi
Walter Setti, Helene Vitali, Claudio Campus, Lorenzo Picinali, Monica Gori

#029 - The associative property holds for combination of auditory, visual, and tactile signals in multisensory decisions
Thomas Otto

#030 - The effect of Audio-visual-haptic Training on Overtaking Learning Outcomes in a VR and Computer Environment
Michael Batterley, Georg Meyer, Mark White

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SESSION 1

#031 - The developing homunculus: neuroplasticity in children with and without upper limb differences
Raffaele Tucciarelli, Laura Bird, Mathew Kollamkulam, Harshal Sonar, Jamie Paik, Danielle Clode, Dorothy Cowie, Tamar Makin

#032 - Memory-guided reaching movements toward haptically-encoded spatial locations
Ivan Camponogara, Faisal Abdulhadi, Robert Volcic

#033 - Neural Correlates Underlying the Interaction and Integration of the Audiovisual Personal Identity and Audiovisual Speech
Dong Chenjie, Qiu Lizhen, Wang Suiping

#034 - Modelling Multisensory Causal Inference with Scikit-NeuroMSI
Renato Paredes, Juan Cabral, Peggy Seriès

#035 - The prototypical expressions can facilitate the perception of various positive emotions through face, voice, and touch
Rika Oya, Akihiro Tanaka

#036 - The facilitating effect of maternal odor on rapid face categorization in the infant brain declines over the first year
Diane Rekow, Jean-Yves Baudouin, Anna Kiseleva, Bruno Rossion, Karine Durand, Benoist Schaal, Arnaud Leleu

#037 - Audiovisual temporal recalibration modulates eye movement-related eardrum oscillations
Hossein Abbasi, Cynthia D. King, Stephanie Lovich, Brigitte Röder, Jennifer M. Groh, Patrick Bruns

#038 - Characterizing the context-dependence of head pointing errors in virtual reality
Davide Esposito, Alice Bollini, Monica Gori

#039 - Neural speech tracking benefit of lip movements predicts behavioral deterioration when the speaker's mouth is occluded
Patrick Reisinger, Marlies Gillis, Nina Suess, Jonas Vanthornhout, Chandra Haider, Thomas Hartmann, Konrad Schwarz, Tom Francart, Nathan Weisz

#040 - Effects of Crossmodal Association Learning on the Processing of Audiovisual Spatial Information: An EEG Study
Cora Kubetschek, Brigitte Röder, Patrick Bruns

#041 - Psychophysical investigation of localization of audio-tactile stimuli in active touch
Giulia Esposito, Arthur Courtin, Olivier Collignon, André Mouraux

#042 - Exploring whether hMT+/V5 represents spatial frequencies when processing moving visual and auditory information.
Marco Barilari, Gloria Calafatello, Micah Murray, Anna Gaglianese, Olivier Collignon

#043 - Landmark distortions of target localizations within and across modalities
Paula Soballa, Christian Frings, Simon Merz

POSTER LIST
SESSION 1

#044 - Psychological relativity in tactile motion perception
Nicolas Pélegrin

#045 - Distinct profiles of multisensory processing between professional goalkeepers and outfield football players
David Mcgovern, Michael Quinn, Rebecca Hirst

#046 - Reaching and Grasping time in infants: the effect of an early visual impairment
Stefania Petri, Walter Setti, Claudio Campus, Helene Vitali, Eleonora Mascherpa, Sabrina Signorini, Francesca Tinelli, Sandra Strazzer, Giuseppina Giammari, Elena Cocchi, Monica Gori

#047 - Perceiving more than expected: the deviation of responses to bimodal stimuli from race model prediction
Marta Guarischi, Nicolò Balzarotti, Giulia Cappagli, Claudio Campus, Federica Morelli, Guido Catalano, Sabrina Signorini, Monica Gori

#048 - Dynamic spatial representation for navigation activates the premotor cortex in blind subjects: virtual tools can reshape the peripersonal space
Elena Aggius Vella, Daniel-Robert Chebat, Shachar Maidenbaum, Amir Amedi

#049 - Sighted people overestimate the experience with and ability of blind people in tactile face recognition
Elizabeth Saccone, Elizabeth Musz, Zaida Mcclinton, Marina Bedny,

#050 - Dissociation between dreams and wakefulness: Insights from body and action representations of rare individuals with acquired and congenital somatosensory deficits
Ishan-Singh Chauhan, Peggy Mason, Jonathan Cole, R. Chris Miall, Fabrice Sarlegna

#186 - Blindness does not hamper extension of touch localization on tools
Fabio Cécile, Salam Bahmad, Roméo Salemme, Luke Miller, Alessandro Farnè

POSTER LIST
SESSION 2

#051 - How do people navigate around physical vs. visual-only augmented obstacles?
Ilan Vol, Shachar Maidenbaum

#052 - The influence of social interactions on visuotactile causal and perceptual inference
Ugo Giulio Pesci, Virginia Spagnuolo, Uta Noppeney, Matteo Candidi

#053 - Tilting the body affects perceived haptic length
Meaghan Mcmanus, Nikola Zalomska, Laurence Harris, Katja Fiehler

#054 - Mirror invariance for objects and Braille letters in congenitally blind people; an fMRI study.
Maksymilian Korczyk, Katarzyna Rączy, Marcin Szwed

#055 - Feedback processing shapes the categorical organization of the ventral stream
Marius Peelen

#056 - Crossmodal temporal functions are unaffected by transient periods of blindness or deafness
Patrick Bruns, Pia Ley, Stephanie Badde, Thomas Lenarz, Ramesh Kekunnaya, Brigitte Röder

#057 - Semantic meaning guides audiovisual attention in a continuous manner
Kira Wegner-Clemens, George Malcolm, Sarah Shomstein

#058 - Allocentric reference frames are robust to changes in body tilt, but egocentric reference frames are not.
Jong-Jin Kim, Pierre-Pascal Forster, Meaghan Mcmanus, Katja Fiehler, Laurence Harris

#059 - Perception of the McGurk Effect in people with one eye depends on whether the eye is removed during infancy or adulthood
Stefania Moro, Faizaan Qureshi, Jennifer Steeves ,

#060 - An EEG Investigation of Multisensory Integration in ADHD Adults
Carolynn Hare, Carol Atta, Glenda Zhai, Michelle Luszawski, Ryan Stevenson

#061 - How does simulated eye height affect size perception in different postures?
Fatemeh Ghasemi, Laurence Harris, Bjoern Joerges

#062 - How the characteristics of a virtual environment affect the perception of moving through it
Ambika Bansal, Meaghan Mcmanus, Katja Fiehler, Laurence Harris

#063 - Semantic congruency modulates the speed-up of multisensory responses
Kalvin Roberts, Ines Jentzsch, Thomas Otto

#064 - Vestibular influence on the audio-visual bounce effect
Jonas Vibell

#065 - Age-related effects on proprioception and gait
Fang Jiang, Amy Morris, Catrina Aglubat, Corinne Masegian, Angela Zhang, Morgan Flynt, Benjamin Lozo, Brian Szekely, Maddie Taylor, Nicholas Murray

#066 - Precision and Bias in the Perception of Object Size in Microgravity
Björn Jörges, Nils Bury, Meaghan Mcmanus, Ambika Bansal, Robert Allison,Michael Jenkin, Laurence Harris

POSTER LIST
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#067 - Accuracy of perceived position of relatively rotating sound during passive body rotation

Shuichi Sakamoto, Soichiro Moribe

#068 - Effect of postural instability on passable width perception in older adults

Naoki Kuroda, Ryo Teraoka, Shinya Harada, Wataru Teramoto

#069 - Adaptation to Visuomotor Delays and Its Transfer to Feedback Control of Reaching Movements

Anne Hoffmann, Frédéric Crevecoeur, Ilana Nisky

#070 - Visual-to-auditory conversion methods for sensory substitution: sound spatialization only versus cross-modal correspondence

Camille Bordeau, Florian Scalvini, Cyrille Migniot, Julien Dubois, Maxime Ambard

#071 - Path integration of blind individuals using uni-sensory feedback

Shehzaib Shafique, Walter Setti, Claudio Campus, Alessio Del Bue, Monica Gori

#072 - Investigating serial dependence in visual time perception

Jessica Bertolasi, Anna Vitale, Davide Esposito, Monica Gori

#073 - Eye movement-related eardrum oscillations: signature of an active sensing process or epiphenomenon?

Felix Bröhl, Christoph Kayser

#074 - Audio-Visual Processing in Primary Visual Cortex by a Dynamical Model of Pyramidal Cell Computation

Daniel Schmid, Heiko Neumann

#075 - The impact of sensory cues during multiple object tracking

Julia Föcker, Lily Hughes, Maximilian Wilhelm, Hauke Meyerhoff, Niko Kargas

#076 - Higher order informational content: the perfect tool for multisensory research?

Daniele Marinazzo

#077 - Cross-modal active sensation in mice: Touching what you see

Adrian Hoffmann, Fritjof Helmchen

#078 - Auditory spatial localization in children: accuracy and precision along the azimuthal and elevation planes

Calafatello Gloria, Tonelli Alessia, Zanchi Silvia, Amadeo Maria Bianca, Tammurello Carolina, Setti Walter, Gori Monica

#079 - Using a hand-held tool modifies proprioceptive representations of the user's arm and tool

Pfeifer Leo, Peviani Valeria, Miller Luke

#080 - The boosted subjective time compression induced by enriching sensory feedback of a voluntary action

Ueda Sayako, Shimoda Shingo

#081 - Visual bias on bimanual tactile perception: investigation of the neural mechanisms using neurocomputational modelling

Cristiano Cuppini, Melissa Monti, Elisa Magosso, Jeffrey Yau

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SESSION 2

#082 - Visual-nociceptive integration during rubber hand illusion
Sara Coppi, H. Henrik Ehrsson

#083 - Does audio-visual information result in improved health-related decision-making and knowledge when compared with audio-only or visual-only information? A systematic review & meta-analysis
Jemaine Stacey, Christopher Atkin, Helen Henshaw, Mengfan Wu, Katherine Roberts, Harriet Allen, Stephen Badham

#084 - The effect of physical motion on Human spatial memory and neural representations of space
Shachar Maidenbaum

#085 - Auditory pitch modulates the localization of audiotactile stimuli during active touch
Maria Casado-Palacios, Giulia Esposito, Alessia Tonelli, Arthur Courtin, Olivier Collignon, Monica Gori, André Mouraux

#086 - Interhemispheric asymmetry of visual evoked potentials underlies crossmodal interaction between nociception and vision
Monika Halicka, Kuzminova Avgustina, Valéry Legrain

#087 - Assessing and Optimising Audio-visual Integration for Listening
Lida Alampounti, Hannah Cooper, Jennifer Bizley

#088 - Radiant thermal signals give rise to a contactless rubber hand illusion
Laura Crucianelli, Henrik Ehrsson

#089 - The cognitive mechanisms underlying the variation of McGurk illusion susceptibility
Chenjie Dong, Qi Yao, Yunsong Li, Zhengye Wang, Ruqin Li, Suiping Wang

#090 - Immigration modulates audiovisual emotion integration in adults: the effect of the host culture and migration itself
Anna Nakamura, Hisako Yamamoto, Akihiro Tanaka

#091 - Plasticity of word processing networks in brains of congenitally blind individuals
Marta Urbaniak, Malgorzata Paczynska, Alfonso Caramazza, Lukasz Bola

#092 - The subjective experience of using a newly-learned cue
Melissa Ramsay, Chris Allen, Meike Scheller, Marko Nardini

#093 - The effect of postural orientation around the pitch axis on the haptic perception of vertical.
Elef Schellen, Eva Ark, Michael Jenkin, Robert Allison, Nils Bury, Rainer Herpers, Harris Laurence

#094 - Probabilistic computations in body perception
Valeria Peviani, Luke Miller, Pieter Medendorp

#095 - The Effect of Stimulus Complexity on Perceived Simultaneity in Virtual and Augmented Reality
Min Li, Diar Abdlkarim , Vojtech Ryp, Massimiliano Di Luca

POSTER LIST
SESSION 2

#96 - Influence of touch duration on tactile localization on the body
Sergio Tcaci Popescu, Jason Khoury, Kevin O'regan, Matj Hoffmann

#097 - Multi-modal sensory selection assay in mice to explore underlying neural circuits
Mihaela Gerova Mihaela, Vincent Bonon, Asli Ayaz

#98 - Nihil in intellectu nisi prius in sensu¬†?: Knowledge and conceptualisation of olfactory information without the sense of smell.
Eléonore Giraudet, Stefania Mattion, Giada Lettieri, Caroline Huart, Olivier Collignon

#099 - Tracking occluded multisensory objects
Yichen Yuan, Surya Gayet, Nathan Van Der Stoep

#100 - Potential dissociation between pain perception and the modulation of pain-related ongoing neural oscillations
Chiara Leu, Arthur Courtin, Céline Cussac, Giulia Liberati

#101 - Enhancing Learning Outcomes through Multisensory Integration: An fMRI and DTI Study of Audio-Visual Training in Virtual Reality
Kholoud Alwashmi, Georg Meyer, Fiona Rowe

#102 - Only visible flicker helps flutter: Tactile-visual integration breaks in the absence of visual awareness
Sofia Montoya, Stephanie Badde

#103 - How are visuo-haptic object categories formed during childhood?
Eimear Mckenna, Isabella Devine, Rebecca Hirst, Fiona Newell

#104 - Functional implications of a patch/matrix-like compartmental organization in the mouse inferior colliculus
Alexandria Lesicjko, Maria Geffen

#105 - Multimodal integration of emotional robotic stimuli: a reaction time study
Thomas Davies, Niko Kargas, Marise Galvez Trigo, Julia Föcker

#106 - Older adults do not show enhanced benefits from multisensory information on speeded discrimination tasks
Christopher Atkin, Jemaine Stacey, Katherine Roberts, Harriet Allen, Helen Henshaw, Stephen Badham

#107 - Efficient adaptive classification of observers into distinct and diverse categories
Nicolaas Prins

#108 - Inducing Food Craving Using Multisensory Exposure In Indian Population
Koel Das, Avishek Chatterjee, Satyaki Mazumder

#109 - Individual differences in subjective and objective measures of auditory, visual, tactile and cross-modal sensory sensitivity
Rebekah Street, Olivia Carter, Patrick Goodbourn, Jason Forte

#110 Spatial sensory organization around the body: anisotropy of audio-tactile integration
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