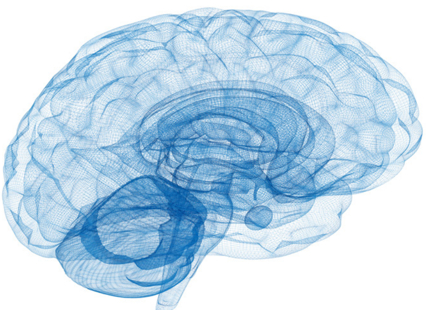
IMRF



Reno, NV | 2024
June 17 - 20

22nd Annual International Multisensory Research Forum

University of Nevada, Reno
College of Science
*Live a life of discovery.*sm

TABLE OF CONTENTS

Schedule Overview........................4-5

Daily Schedules.............................6-9

Conference Venue..........................10

Keynote Speakers......................12-14

Symposia....................................15-44

Talk Sessions............................45-62

Poster Sessions.........................63-92

Committees......................................93

Sponsors....................................94-95

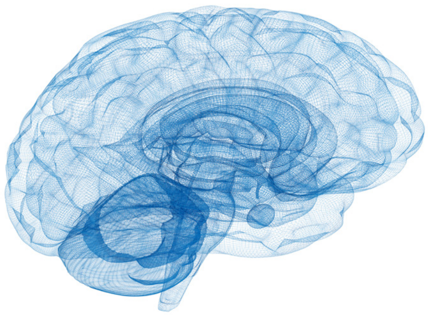
Schedule Overview

Day 1: Monday, June 17, 2024	
11:00 a.m.	Registration
12:00 p.m.	Opening Remarks
12:15 p.m.	Talk Session 1
1:45 p.m.	Poster Session 1
2:15 p.m.	Symposium 1
3:15 p.m.	Coffee
3:45 p.m.	Talk Session 2
5:00 p.m.	Break
5:15 p.m.	Keynote Speaker 1
6:15 p.m.	Break
6:30 - 8:30 p.m.	Reception and Poster Session 1

Day 2: Tuesday, June 18, 2024	
8:00 a.m.	Coffee/Continental Breakfast
8:30 a.m.	Talk Session 3
9:30 a.m.	Coffee
10:00 a.m.	Symposium 2
11:15 a.m.	Poster Session 2
12:00 p.m.	Lunch and Poster Session 2
1:30 p.m.	Symposium 3
3:00 p.m.	Coffee
3:30 p.m.	Symposium 4
5:00 p.m.	Break
5:15 - 6:15 p.m.	Keynote Speaker 2

Day 3: Wednesday, June 19, 2024	
8:00 a.m.	Travel to Tahoe
9:15 a.m.	Coffee/Continental Breakfast
9:45 a.m.	Talk Session 4
11:00 a.m.	Break
11:15 a.m.	Symposium 5 (Invited)
12:30 p.m.	Lunch
1:30 p.m.	Symposium 6
2:45 p.m.	Coffee
3:15 p.m.	Symposium 7 (Invited)
4:15 p.m.	Break
5:15 p.m.	Keynote Speaker 3
6:15 p.m.	Break
6:30 p.m.	Banquet
9:00 - 10:15 p.m.	Travel from Tahoe

Day 4: Thursday, June 20, 2024	
8:00 a.m.	Coffee/Continental Breakfast
8:30 a.m.	Talk Session 5
9:45 a.m.	Coffee
10:00 a.m.	Symposium 8
11:15 a.m.	Break
11:30 a.m.	Talk Session 6
12:45 p.m.	Grab and Go Lunch
1:00 p.m.	Business Meeting



	Monday, June 17	Tuesday, June 18	Wednesday, June 19	Thursday, June 20
8:00 a.m.		Coffee Talk Session 3	Travel to Tahoe	Coffee Talk Session 5
9:00 a.m.		Coffee	Coffee Talk Session 4	Coffee
10:00 a.m.		Symposium 2		Symposium 8
11:00 a.m.	Registration	Posters	Break Symposium 5 (Invited)	Break Talk Session 6
12:00 p.m.	Opening Remarks Talk Session 1	Lunch and Posters	Lunch	Grab n Go Lunch Business Meeting
1:00 p.m.	Posters	Symposium 3	Symposium 6	
2:00 p.m.	Symposium 1		Coffee	
3:00 p.m.	Coffee Talk Session 2	Coffee Symposium 4	Symposium 7 (Invited)	
4:00 p.m.			Break	
5:00 p.m.	Break Keynote 1	Break Keynote 2	Keynote 3	
6:00 p.m.	Break Reception and Posters		Break Banquet	
7:00 p.m.				
8:00 p.m.				
9:00 p.m.			Travel from Tahoe	

Daily Schedules

Day 1: Monday, June 17, 2024

TIME	EVENT	PLACE	DETAILS
11:00 a.m.	Registration	DMSC Foyer	-
12:00 p.m.	Opening Remarks	DMSC 110	-
12:15 p.m.	Talk Session 1	DMSC 110	**Topic:** Haptic, Tactile & Somatosensory **Speakers:** Kasia Ciesla, Stephanie Badde, Alix Macklin, Anupama Nair, Claire Manley & Abdulrabba Sadiya
1:45 p.m.	Poster Session 1	DMSC Foyer	-
2:15 p.m.	Symposium 1	DMSC 110	**Topic:** Contributions of Innate Constraints & Experience to the Development of Visual Cortex - Evidence from Infants & Blind Adults **Speakers:** Olivier Collingnon, Vladislav Ayzenberg, Heather L. Kosakowski, & Elizabeth J. Saccone
3:15 p.m.	Coffee	DMSC Foyer	-
3:45 p.m.	Talk Session 2	DMCS 110	**Topic:** Modeling **Speakers:** Vincent Billock, Wenhao Zhang, Paul MacNeilage, Hans Colonius & Marissa Fassold
5:00 p.m.	Break	-	-
5:15 p.m.	Keynote Speaker 1	DMSC 110	**Topic:** To integrate or not to integrate: Solving the binding problem in a multisensory world **Speaker:** Dr. Uta Noppeney
6:15 p.m.	Break	-	-
6:30 - 8:30 p.m.	Reception and Poster Session 1	DMSC Foyer & Keck Museum	-

Day 2: Tuesday, June 18, 2024

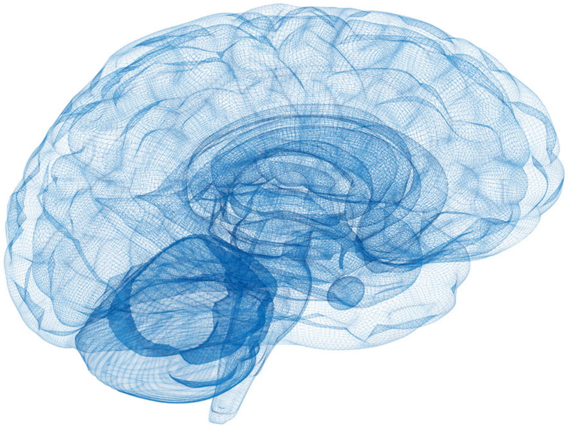
TIME	EVENT	PLACE	DETAILS
8:00 a.m.	Coffee	DMSC Foyer	-
8:30 a.m.	Talk Session 3	DMSC 110	**Topic:** Audio-visual **Speakers:** Chase Mackey, Kalvin Roberts, Yike Li & Emily Cunningham
9:30 a.m.	Coffee	DMSC Foyer	-
10:00 a.m.	Symposium 2	DMSC 110	**Topic:** From Lipreading to Listening: How Visual Cues Shape Auditory Speech Processing **Speakers:** Aaron R. Nidiffer, Kaja Rosa Benz, David Brang, Cody Zhewei Cao & John F. Magnotti
11:15 a.m.	Poster Session 2	DMSC Foyer	-
12:00 p.m.	Lunch and Poster Session 2	DMSC Foyer	-
1:30 p.m.	Symposium 3	DMSC 110	**Topic:** From Passive to Active: The Influence of Active Perception on Multisensory Processing **Speakers:** James Negen, Davide Esposito, David Alais, Roberto Arrighi, Alessia Tonelli & Brian Székely
3:00 p.m.	Coffee	DMSC Foyer	-
3:30 p.m.	Symposium 4	DMSC 110	**Topic:** Unravelling the Neural Mechanisms of Multisensory Self-Motion Processing: From Primate Models to Clinical Applications **Speakers:** Yong Gu, Annalisa Bosco, Sarah Marchand, Sabrina Pitzalis, Mark W. Greenlee & Elena Aggius-Vella
5:00 p.m.	Break	-	-
5:15 - 6:15 p.m.	Keynote Speaker 2	DMSC 110	**Topic:** Computing the location(s) of sound(s) in the visual scene **Speaker:** Dr. Jennifer Groh

Day 3: Wednesday, June 19, 2024

TIME	EVENT	PLACE	DETAILS
8:00 a.m.	Travel to Tahoe	-	Meet at Fleischmann Agriculture for buses
9:15 a.m.	Coffee	NTEC	-
9:45 a.m.	Talk Session 4	NTEC	**Topic:** Learning **Speakers:** Ansley Kunnath, Marko Nardini, Ladan Shams, Walter Setti & Meike Scheller
11:00 a.m.	Break	NTEC	-
11:15 a.m.	Symposium 5 (Invited)	NTEC	**Topic:** Processes of Multisensory Learning **Speakers:** Ladan Shams, Marko Nardini, Ulrik Beierholm, Fiona Newell & Aaron Seitz
12:30 p.m.	Lunch	NTEC	-
1:30 p.m.	Symposium 6	NTEC	**Topic:** Multisensory Development in Humans from Birth through Young Adulthood **Speakers:** Mark T. Wallace, Marcus R. Watson, David Tovar, Monica Gori & Julien Favre
2:45 p.m.	Coffee	NTEC	-
3:15 p.m.	Symposium 7 (Invited)	NTEC	**Topic:** Multisensory Processing in Mouse & Insect Models **Speakers:** Jennifer Hoy, David Feldheim, Ben Cellini & Saumya Gupta
4:15 p.m.	Break	NTEC	-
5:15 p.m.	Keynote Speaker 3	NTEC	**Topic:** Mastering the Art of Multisensory Integration:A Guide to Success **Speaker:** Dr. Marc Ernst
6:15 p.m.	Break	NTEC	-
6:30 p.m.	Banquet	NTEC	-
9:00 - 10:15 p.m.	Travel from Tahoe	-	-

Day 4: Thursday, June 20, 2024

TIME	EVENT	PLACE	DETAILS
8:00 a.m.	Coffee	DMSC Foyer	-
8:30 a.m.	Talk Session 5	DMSC 110	**Topic:** Audio-visual - Special Populations **Speakers:** Jesse Breedlove, Lotfi Merabet, Ghazaleh Mahzouni & Yi Yuan
9:45 a.m.	Coffee	DMSC Foyer	-
10:00 a.m.	Symposium 8	DMSC 110	**Topic:** Shifting Sensory Reliance - Adaptive Strategies in Vision Impairment & Blindness **Speakers:** Adrien Chopin, Catherine Agathos, Jade Guénot, Santani Teng & Haydée García-Lázaro
11:15 a.m.	Break	DMSC Foyer	
11:30 a.m.	Talk Session 6	DMSC 110	**Topic:** Visual-vestibular Interactions & Self-motion **Speakers:** Björn Jörges, Val Rodriguez, Christian Sinnott, Anne-Laure Rineau & Fatemeh Ghasemi
12:45 p.m.	Grab and Go Lunch	DMSC Foyer	-
1:00 - 2:00 p.m.	Business Meeting	DMSC 110	



Conference Venue

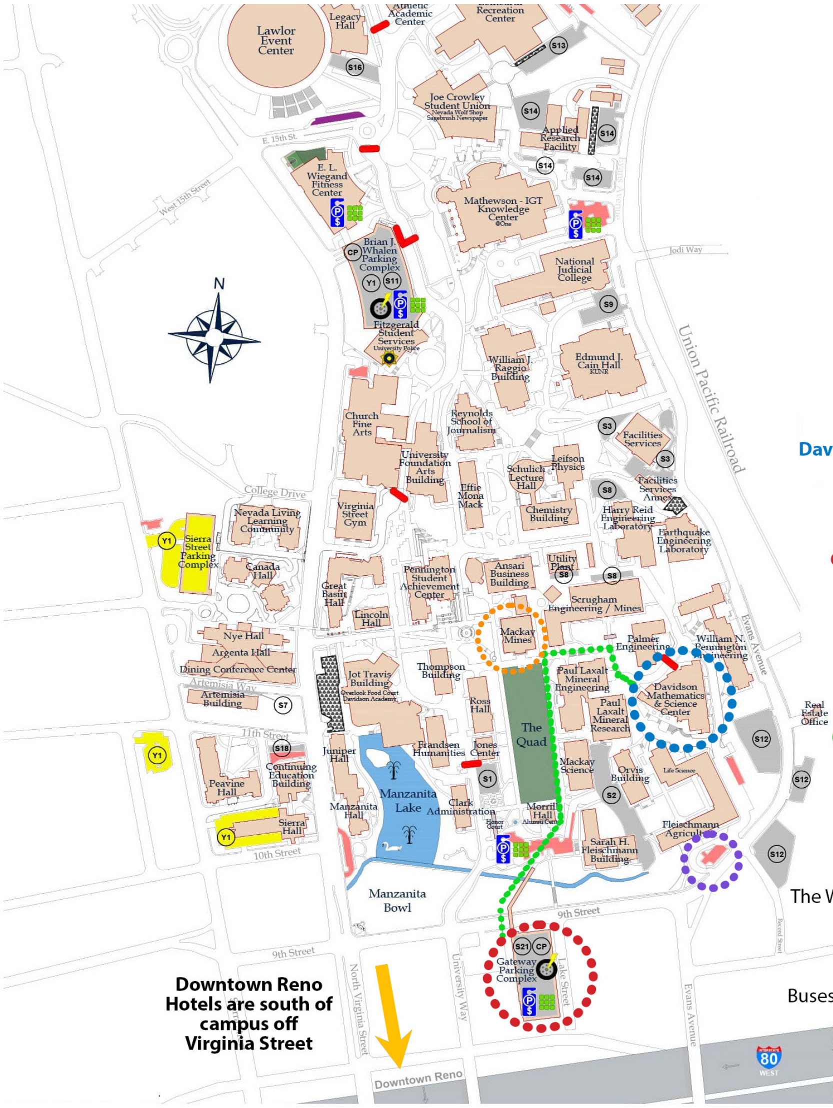
Reno-Tahoe

The city of Reno is a four-hour drive east of San Francisco in the foothills of the Sierra Nevada mountains. Yosemite National Park is a three-hour drive to the south, and Lake Tahoe is only a 45-minute drive from downtown.

Reno is a tourist destination due to the easy access to stunning outdoor recreation opportunities as well as numerous in-town entertainment options, including highly-rated restaurants, bars, and yes, casinos.

The University campus is located just north of downtown, within easy walking distance of hotels and entertainment districts.

The conference will be held on the campus of the University of Nevada, Reno in the Davidson Math and Science Center on June 17, 18 and 20. On June 19, the conference will take place at the North Tahoe Events Center on the beach at Lake Tahoe in the town of Kings Beach.



Downtown Reno Hotels are south of campus off Virginia Street

IMRF Sessions will be held in the **Davidson Math and Science Center (in the blue circle)**.

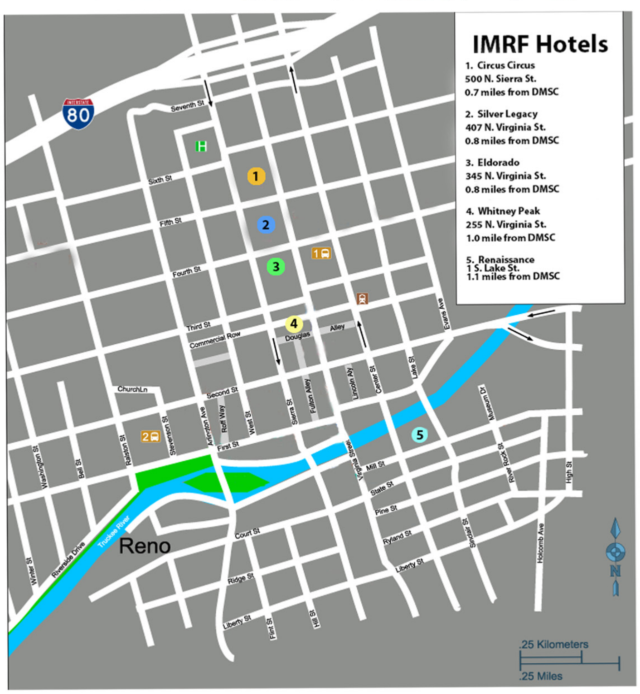
Parking for IMRF available on the 2nd and 3rd floors of the **Gateway Parking Complex (in the red circle)**. Purchase a parking permit on the website or at registration.

Pedesterian bridge to campus is on the 4th Floor. **Follow the walking path (shown by the green dots)** to Davidson Math and Science Center.

ADA access through Paul Laxalt Mineral Engineering

The Welcome Social on Monday night will include a tour of the **Keck Mineral Museum (in the orange circle)**

Buses for A Day at the Lake will pick up in front of Fleischmann Agriculture **(in the purple circle)**



University of Nevada, Reno Campus Map (top)

Downtown Reno Map (left)

Keynote Speaker

Dr. Uta Noppney

Radboud University, Netherlands

Uta Noppeney studied medicine and philosophy at the University of Freiburg (Germany), University College London (UK) and Johns Hopkins University (Baltimore, USA). She received a degree in medicine (1997, Freiburg University, Germany), a doctorate in medicine (1998, Freiburg University) and a PhD in neuroscience (2004, University College London, UK). After training in neurology at the University Hospital in Aachen, she conducted neuroscience research at the Wellcome Trust Centre for Neuroimaging, University College London (UK). In 2005, she became independent research group leader at the Max Planck Institute for Biological Cybernetics in Tübingen (Germany). In 2011, she was appointed Professor of Computational Neuroscience and director of the Computational Neuroscience and Cognitive Robotics Centre at the University of Birmingham (UK). Since 2019/2020, she has been Principal Investigator at the Donders Centres for Cognitive Neuroimaging and Neuroscience and Professor of Systems Neuroscience at the Neurophysics department of the Donders Institute for Brain, Cognition and Behaviour, Radboud University (Netherlands).

To integrate or not to integrate: Solving the binding problem in a multisensory world

Adaptive behavior in a complex, dynamic, and multisensory world requires the brain to solve the causal inference or binding problem, deciding whether signals come from common sources and should hence be integrated or from independent sources and be segregated. In this talk, I will delve into our recent research, spanning behavioral, computational, and neural systems levels, to explore how the brain tackles this challenge. Combining psychophysics, computational modelling and neuroimaging (fMRI, EEG) our results show that the brain arbitrates between sensory integration and segregation consistent with the principles of Bayesian Causal Inference by dynamically encoding multiple perceptual estimates across the cortical hierarchy. Next, I will explore how prior expectations and attentional mechanisms can modulate sensory integration. Finally, I will show how causal inference influences the brain's rapid recalibration, enabling dynamic adaptation to changes in the external environment and within the sensorium.

Keynote Speaker

Dr. Jennifer Groh

Duke University, United States

Jennifer M. Groh is Professor of Psychology & Neuroscience, Neurobiology, Computer Science, and Biomedical Engineering at Duke University, where she is a member of the Center for Cognitive Neuroscience and the Duke Institute for Brain Sciences. Her research concerns how the brain represents spatial information and performs computations on those representations. Her discoveries have shed light on how the brain transforms auditory signals to permit communication with visual signals - despite major differences in the neural "language" used by each sense. She is the recipient of numerous awards including a John Simon Guggenheim fellowship. She has authored many scientific publications as well as a well-regarded book for a general audience (Making Space: How the Brain Knows Where Things Are, Harvard University Press, 2014) and a related popular Coursera course, The Brain and Space.

Computing the location(s) of sound(s) in the visual scene

How the auditory system encodes the locations of sounds in the visual scene involves rich computational problems concerning how spatial locations are defined and represented. Information about eye movements is critical, since eye movements move the retina with respect to the head/ears. We recently discovered that the brain sends signals regarding eye movements to the ears, causing oscillations of the eardrum and producing self-generated sounds that can be detected via earbud microphones (Gruters et al, PNAS 2018). These eye movement-related eardrum oscillations (EMREOs) likely constitute the first step of a coordinate transformation of auditory signals into common coordinates with the visual system (Lovich et al PNAS 2023). Coding of multiple stimuli is also essential, as the natural world is replete with multiple visual and auditory stimuli at any given time. We recently proposed that multiple stimuli may be encoded via multiplexing, in which neural activity fluctuates across time to allow representations to encode more than one simultaneous visual or auditory stimulus (Caruso et al, Nat Comm 2018; Jun et al. eLife 2022, Schmehl et al. eLife 2024).

These findings all emerged from experimentally testing computational models regarding spatial representations and their transformations within and across sensory pathways, highlighting the importance of theory in guiding experimental science.

Keynote Speaker

Dr. Marc Ernst

Ulm University, Germany

Marc O. Ernst, Chair of Applied Cognitive Psychology at Ulm University, Germany. Marc Ernst studied Physics in Heidelberg and Frankfurt/M. He received his PhD for work conducted at the Max Planck Institute for Biological Cybernetics in Tübingen already working on human multisensory processing under the supervision of Heinrich H. Bülthoff. In 2000/2001 he went to UC Berkeley for a postdoc with Martin S. Banks, which resulted in some influential papers on multisensory integration. After this postdoc, he returned to the Max Planck Institute where he became PI and Independent Max Planck Research Group Leader heading the Multisensory Perception for Action Group. He participated in several collaborative projects on haptics, sensorimotor learning, and human locomotion and navigation behavior, while developing multisensory virtual reality methods for the study of human behavior. In 2011, he became full professor in the department of Biology of Bielefeld University, co-coordinating the Excellence Cluster CITEC and becoming a scientific director of the Center for Interdisciplinary Research (ZiF). He was a founding Member and President of the EuroHaptics Society and Editor in Chief of the Journal Multisensory Research. In 2016 he was appointed Professor in Psychology at Ulm University and a coordinator of the Cognitive Systems Program at the intersection between Psychology and Computer Science.

Mastering the Art of Multisensory Integration: A Guide to Success

Humans possess multiple sensory systems, including vision, touch, and audition, that empower them to robustly perceive the rich and complex world around them. Perception plays a pivotal role in enabling successful interactions with the environment, while being shaped by some unsuccessful interactions. In this presentation, I offer insights drawn from over two decades of research on human multisensory perception, emphasizing the fusion of behavioral analysis with computational modeling. Early on, it became evident that for humans to effectively engage with their surroundings, the brain must seamlessly integrate multisensory inputs to construct a reliable and accurate multisensory percept. However, the process of multisensory integration is often complicated by the presence of noise and uncertainty at every stage of signal processing, resulting in sensory information that is inherently imprecise, ambiguous, and potentially inaccurate. I will explore various strategies that the nervous system employs to mitigate the adverse effects of noise and uncertainty, enhancing overall performance. Specifically, I will delve into the mechanisms of learning and how our perceptions adapt to the statistical regularities present in a dynamically changing environment. Recently, we had a unique opportunity to study a distinct group of individuals: children born blind with dense bilateral cataracts who underwent surgical treatment later in life, enabling them to regain their sight. This study allowed us to trace the developmental trajectory of multisensory perception and action, revealing a remarkable level of plasticity in many multisensory processes. Interestingly, while some cognitive functions, such as refined control of grasping, exhibited limited improvement, these studies underscored the complex interplay between multisensory perception, cognitive development, and adaptive plasticity in response to novel and changing sensory inputs.

Symposium One

June 17 from 2:15 - 3:15 p.m. in DMSC 110

Symposium Organizer: Elizabeth Saccone

Contributions of Innate Constraints and Experience to the Development of Visual Cortex: Evidence from Infants and Blind Adults

How do innate constraints and experience contribute to the function of the human visual system? This symposium presents complementary insights into this question from studies with sighted infants and adults with different visual experience: congenitally blind and sighted adults. Recent fMRI studies with sighted infants suggest key signatures of visual cortical anatomy and function are present shortly after birth, as featured in the first two talks. Ayzenberg shows large-scale anatomical and functional organization of the visual system is similar across newborns and sighted adults. However, ventral and dorsal pathways have different developmental trajectories; ventral stream connectivity profiles develop later. Kosakowski examines domain-specific functional specialization in infant ventral occipitotemporal cortex (vOTC). In sighted adults, vOTC contains regions preferring different object categories (faces, scenes, bodies). Kosakowski shows these category-specific responses are present shortly after birth. These first two talks highlight similarities between infant and adult brain organization and function. Next, evidence from congenitally blind and sighted adults suggest commonalities but also function differences across populations. Past research found responses to tactile faces and human voices in lateral vOTC (i.e., 'FFA') of blind adults, suggesting a preserved role in person recognition. However, other studies find the lateral vOTC responds to spoken language. Do visual cortices preserve their behavioral role in blindness? Saccone shows a robust preference for language in 'FFA' over other 'human vocalization' conditions, inconsistent with a person-recognition role. Last, Collignon brings together data from both infants and sighted and blind adults. They examine auditory responses to different object categories in the visual system and show greater distinctions between categories in sighted adults than infants, and in blind than sighted adults, suggesting partial similarity across blind and sighted people. Together, these talks provide evidence for innate organization in the human visual system but also reveal the potential to re-tool for non-visual/sensory roles.

#1: From waveform to meaning: Development and reorganization of the dynamics of sound representation in the human brain

Olivier Collignon
University of Louvain & The Sense Innovation and Research Center

After a cascade of processing stages by the human auditory machinery, simple vibration in the air gets perceived as a recomforting voice, a frightening thunder, or a sumptuous symphony of Mozart. How the human brain makes sense of sounds is however scarcely understood. In this talk I will first present a study showing some key maturational differences in how sounds are represented in infancy and adulthood. In a second study, I will show how this process reorganizes in case of early visual deprivation. In both studies, we used electroencephalography to characterize the time course of brain representation elicited by sounds belonging to eight categories in sighted infants and adults as well as in early blind individuals. We use time-resolved multivariate decoding analyses to show enhanced unique sound representation over a protracted period in adults compared to infants and in blind compared to sighted. We then rely on representational similarity analysis that compared brain representation with different sound models across time: (i) Modulation Transfer Function simulating early stage of acoustic processing, (ii) layers of a deep neural network (YAMNET), (iii) models based on the categorical membership of sounds (and participant specific similarity ratings of each sound pairs in adults). Our results reveal multi-level differences in brain networks coding for sounds across development and across sensory experience; with enhanced intermediate-level acoustic discrimination earlier in time, followed by an increased categorical coding of sounds in adults compared to infants, and in blind compared to sighted people.

#2: The building blocks of vision: Cortical and subcortical organization of the newborn visual system

Vladislav Ayzenberg & Michael Arcaro
University of Pennsylvania

Understanding the anatomical and functional organization of the visual system at birth provides critical insights into the intrinsic constraints on postnatal experience-driven development. Using resting-state fMRI and diffusion tensor imaging, we examined the cortical and subcortical organization of the visual system in neonates (37-42w gestation). We used an adult probabilistic atlas of retinotopic maps (Wang et al. 2015) to identify putative visual areas in neonates. To achieve this, each neonate's cortical surface was registered to an adult cortical surface template and the adult probabilistic atlas was projected onto each neonate's cortical surface. Functional correlations between cortical areas revealed that the infant visual system exhibits an adult-like hierarchical organization, including distinct clusters within the occipital cortex and along ventral, lateral, and dorsal visual pathways. Direct comparisons between neonates and adults revealed that correlation patterns within occipital and dorsal areas were more adult-like than ventral and lateral areas. Additionally, we examined the structural connections between visual cortex and the pulvinar, a subcortical structure that is extensively interconnected with the entire visual cortex in adults and plays a crucial role in visual processing. Probabilistic tractography analyses reliably identified white matter pathways between the pulvinar and each cortical area. However, the maturity of cortical connectivity patterns within the pulvinar varied, with ventral areas showing a less adult-like organization compared to occipital, lateral, or dorsal regions. Overall, our findings indicate that the large-scale anatomical and functional organization of the visual system is established by birth, with dorsal cortex appearing relatively more mature than ventral cortex.

#3: Category selectivity in human infant ventral temporal cortex

Heather L. Kosakowski **1, Michael A. Cohen 2,3, Lyneé Herrera 4, Boris Keil 5, Isabel Nichoson 6, Atsuhi Takahashi 2, Nancy Kanwisher 2, & Rebecca Saxe 2**
1 Harvard University, 2 Massachusetts Institute of Technology, 3 Amherst College, 4 University of Denver, 5 Mittelhessen University of Applied Science, & 6 Tulane University

Human occipitotemporal cortex has regions that selectively respond to distinct visual object categories. The fusiform face area (FFA), parahippocampal place area (PPA), and fusiform body area are in ventral temporal cortex (VTC) and respond selectively to faces, scenes, and bodies, respectively. In lateral occipitotemporal cortex, the occipital face area (OFA), occipital place area (OPA), and extrastriate body area (EBA) also have category selective responses. To determine if any region is category-selective in infancy, we collected functional magnetic resonance imaging (fMRI) data from infants while they watched videos of faces, bodies, objects, and scenes using a custom 32-channel head coil. Infants with sufficient data for functional region of interest (fROI) analyses (n=19) had face-, scene-, and body-selective responses in FFA, PPA, and EBA, respectively. OFA, OPA, and FBA responses did not meet the criteria for selectivity. To investigate when in infancy face selectivity appears, we combined these data with an older fMRI dataset (combined n=37). In OFA, we found an age by condition interaction. Conversely, while the overall magnitude of response changed as a function of age in FFA, there was no age by condition interaction. Further, older infants (n=18, 5.2-9.6 months) had face-selective responses in both OFA and FFA whereas only FFA was face-selective in younger infants (n=19, 2.5-5.1 months). Taken together, these results suggest that face selectivity is present in FFA as early as we can measure and appears in OFA months later. These results importantly constrain the amount of post-natal experience required to develop selective responses to faces.

#4: In people born blind, lateral vOTC specializes for language, not voices

***Elizabeth J. Saccone*, Akshi, & Marina Bedny**
Johns Hopkins University

The lateral ventral occipitotemporal cortex (vOTC) of sighted adults contains a region specialized for recognizing faces (fusiform face area; FFA). How does experience as opposed to innate constraints contribute to face specialization? We test 'FFA' function in congenitally blind adults to answer this question. Previous studies report that lateral vOTC of blind adults responds more to touching models of faces versus scenes and to human vocalizations over non-human sounds (Ratan Murty et al., 2020, PNAS), suggesting a preserved role in person recognition. However, lateral vOTC also responds to spoken and written (Braille) language in blindness. Does this region support person recognition or language processing in people born blind? Congenitally blind, English-speaking adults (N=16) heard English sentences, foreign speech, non-verbal vocalizations (e.g., laughter) and control scene sounds (e.g., forest sounds) during a 1-back task. Participants also performed a tactile face 'localizer' task, touching 3D-printed models of faces and control scenes. We identified individual-subject ROIs preferring tactile faces > scenes in the anatomical location of the sighted FFA. In blind people, the tactile 'FFA' robustly preferred language over all other auditory conditions. We next identified vocalization-preferring voxels in the FFA location using a leave-one-run-out procedure. All vocalization-preferring voxels responded most strongly to spoken language, followed by foreign and non-verbal vocalizations, and lowest to scene sounds. Results do not support a behavioral role of lateral vOTC in agent recognition for blind people. We hypothesize that connectivity with communication-relevant networks leads to specialization for faces (sighted) and language (blind) as a function of experience.

Symposium Two

June 18 from 10:15 - 11:30 a.m. in DMSC 110

Symposium Organizer: David Brang

From Lipreading to Listening: How Visual Cues Shape Auditory Speech Processing

Extensive research has shown that visual speech alters auditory speech behaviors and neural responses. For example, in a crowded bar, visual speech improves the intelligibility of heard speech and strengthens a listener's attention to the speaker. While research has focused on localizing the effects of multisensory speech integration (e.g., that silent lipreading activates auditory cortex and that the McGurk effect is dependent on the left pSTS) less emphasis has been placed on identifying the representational content of these multisensory signals. Indeed, recent research has indicated a wealth of speech relevant information is present in visual speech including linguistic content present in lipreading, statistical correspondences between lip width and relative pitch, the prediction of transient and ongoing timing cues, gender and identity prediction of pitch, the congruence of gestures with auditory content, among others. Because of the complexity of the data available in visual speech, it remains poorly understood how these features support speech perception and comprehension, the mechanisms through which visual information influences the auditory system, and to what degree the use of these visual features is task dependent. In this symposium, our panel will discuss recent advances in our understanding of how visual speech information is used to support speech perception and comprehension through a multimodal lens (including behavior, EEG, MEG, fMRI, and intracranial recordings in humans). Specifically, the talks will show evidence that (1) eye movements track the acoustic envelope during silent visual speech,(2) the visual system represents acoustic dynamics and linguistic information, (3) lipreading information can be decoded from auditory regions, (4) visual speech can help restore spectral and temporal information to the auditory system, and (5) visual speech suppresses the representations of incompatible auditory features.

#1: Visual speech qua speech? Unraveling the hierarchy of audiovisual speech

Aaron R. Nidiffer & Edmund C. Lalor
University of Rochester

Human communication is largely underpinned by an auditory hierarchy where complex spectrotemporal speech patterns are carried through to meaning via a series of linguistic transformations. Seeing a speaker's face endows us with a range of benefits that ultimately boosts speech comprehension. Improvements to selective attention and acoustic processing are thought stem from redundant audiovisual dynamics. Other findings such as the McGurk Effect and the existence of a unique audiovisual lexical neighborhood suggest that the auditory and visual systems produce at least partially independent and complementary linguistic representations. Indeed, behavioral and neural findings have made it clear that "all levels of speech patterns (from features to connected speech) that can be heard can also be visually perceived." We conducted a series of visual and audiovisual speech experiments aimed at dissecting responses to multiple features embedded in visual speech to better understanding how they enhance acoustic and linguistic representations, cognition, and ultimately comprehension. We find evidence for the coexistence of two previously defined forms of speech in the visual system: one is mostly redundant with acoustic dynamics and a second supplies complementary linguistic information. The visual linguistic representation is predictive of lip-reading performance, enhances acoustic-linguistic processing when the acoustics are degraded, and depends on the detailed configuration of the articulators. We interpret our findings in context of a theoretical framework supporting multiple levels of visual integration along the acoustic linguistic hierarchy. Finally, we discuss how level of visual speech processing and integration might map to dissociable behavioral and perceptual effects.

#2: Eye-movements track unheard acoustic speech during silent visual speech

***Kaja Rosa Benz* 1, Anne Hauswald 1, Nina Suess 1, Quirin Gehmacher 1, Patrick Reisinger 1, FabianSchmidt 1, Thomas Hartmann 1, & Nathan Weisz 1,2**
1 Centre for Cognitive Neuroscience & 2 Paracelsus Medical University

Behavioral and neuroscientific studies have demonstrated that observing the movements of a speaker's lips aids in speech comprehension. Intriguingly, even when videos of speakers are presented silently, various cortical regions have been found to track auditory features, such as the envelope. However, the cause and function of silent neural speech tracking have remained elusive. Recently, we have shown that when attentively listening to speech, eye movements track low-level acoustic information. If eye movements are also present during the processing of silent videos of speakers, they could provide a straightforward explanation for cortical speech tracking. Yet, whether ocular speech tracking can be observed during silent visual speech and how this influences cortical speech tracking remains unknown. I will present a recent study, in which we used magnetoencephalogram (MEG) and electrooculogram (EOG) to investigate neural and ocular speech tracking while observing silent videos of a speaker. Our main finding is a clear ocular speech tracking effect to the unheard auditory envelope with a dominance <1 Hz, which was not observed for lip movements. Furthermore, we found a <1 Hz effect of unheard auditory envelope tracking in fronto-temporal regions. However, this neural effect was not influenced when controlling for eye movements. Finally, I will present results from an ongoing study investigating silent lip-reading in a deaf population. I will emphasize the role of eye movements in speech processing and simultaneously raise numerous questions regarding their relevance and functionality that can inspire future research.

#3: Auditory cortex encodes lipreading information through spatially distributed activity

David Brang **1, Ganesan Karthik 1, Cody Zhewei Cao 1, Michael I. Demidenko 1, Andrew Jahn 1, William C. Stacey 1, & Vibhangini S. Wasade 2,3**

1 University of Michigan, 2 Henry Ford Hospital, & 3 Wayne State University School of Medicine

Watching a speaker's face improves speech perception accuracy. These benefits are owed, in part, to implicit lipreading abilities present in the general population. While it is established that lipreading can alter the perception of a heard word, it is unknown how information that is extracted from lipread words is transformed into a neural code that the auditory system can use. One influential, but untested, hypothesis is that visual speech modulates the population coded representations of phonetic and phonemic features in the auditory system. This model is largely supported by data showing that silent lipreading evokes activity in auditory cortex, but these activations could alternatively reflect general effects of arousal or attention, or the encoding of non-linguistic features such as visual timing information. This gap limits our understanding of how vision supports speech perception processes. To test the hypothesis that the auditory system encodes visual speech information, we acquired fMRI data from healthy adults and intracranial recordings from electrodes implanted in patients with epilepsy during auditory and visual speech perception tasks. Across both methods, linear classifiers successfully decoded the identity of silently lipread words using the spatial pattern of auditory cortex responses. Examining the time-course of classification using intracranial recordings, lipread words were classified at significantly earlier time-points relative to heard words, suggesting a predictive mechanism for facilitating speech. These results support a model in which the auditory system combines the joint neural distributions evoked by heard and lipread words to generate a more precise estimate of what was said.

#4: Visual speech differently restores temporal and spectral speech information in the auditory cortex

Cody Zhewei Cao**, G Karthik, Areti Majumbar, Andrew Jahn, & David Brang**

University of Michigan

Visual speech enhances speech perception beyond lipreading, potentially restoring spectral (pitch) and temporal (timing) auditory information. For example, listeners can recover spectral information using speakers' mouth width and the speaker's lip closure helps listeners parse the temporal boundary between words. This study investigates if visual speech processing is region-specific, with separate brain areas in the auditory cortex restoring different auditory features, and how visual speech alters auditory system activity patterns. Using functional magnetic resonance imaging (fMRI) on 64 subjects across five speech conditions (auditory-alone original, temporally and spectrally smeared, and audio-visual temporally and spectrally degraded), findings indicate visual speech affects auditory processing differently based on the type of auditory information being restored. Visual cues increased brain activity in the superior temporal gyrus (STG) for both degradation types, with spectral recovery also engaging Heschl's gyrus and temporal recovery affecting anterior STG. Representational Similarity Analysis (RSA) compared audiovisual and auditory-alone conditions, suggesting visual speech employs distinct mechanisms from auditory speech perception. Future analysis with a single-trial-based General Linear Model (GLM) regressor aims to examine if audiovisual speech more closely resembles original auditory speech than audio-alone conditions, indicating visual speech's role in selectively enhancing degraded auditory features.

#5: Suppressed multisensory activity in posterior superior temporal gyrus is related to increased visual benefit during audiovisual speech perception

John F. Magnotti, **Yingjia Yu, Anastasia Lado, Yue Zhang, & Michael S. Beauchamp**
University of Pennsylvania

Humans have the unique ability to decode the rapid stream of language elements that constitute speech. Although auditory noise in the environment interferes with speech perception, visual information from the face of the talker may compensate. The quality of this visual information varies across talkers and words. We first collected behavioral data from 147 participants reporting their perception of a large set of auditory-only (Ao) or audiovisual (AV) single words, with or without added pink noise. Consistent with myriad previous speech perception studies, AV words had greater accuracy than Ao words, especially when auditory noise was added. Driven by differences in phonetic features, visual benefit varied across words. To look for the neural basis of these differences, we presented 4 words with high vs. low visual benefit to 8 epilepsy patients implanted with intracranial EEG electrodes as part of clinical monitoring. We analyzed the high frequency activity (70-150Hz) from 0 to 550ms following auditory speech onset. We found 28 electrodes in the posterior superior temporal gyrus (pSTG) that produced a response to speech stimuli. We found a significant interaction between word type (high vs. low benefit) and presentation format (A vs. AV; $p = 0.003$): Words with more visual benefit showed reduced pSTG activity (118% response to AV vs. 152% for Ao); words with less benefit showed no difference (129%vs. 134%). We propose a model in which visual speech features suppress representations of incompatible auditory features, increasing perceptual accuracy while decreasing the total neural response.

Symposium Three

June 18 from 1:30 - 3:00 p.m. in DMSC 110

Symposium Organizer: Alessia Tonelli

From Passive to Active: the Influence of Active Perception on Multisensory Processing

Many findings in perception have come from studies using passive participants with minimized environmental stimuli and no intentional action directed toward a specific goal. This contrasts with real-world conditions where goal-directed behavior in a rich environment is normal. A crucial aspect involves integrating sensory information with motor actions, enabling individuals to shape their perceptual experiences actively. This symposium will showcase a collection of studies exploring the consequences of individuals' active and sustained engagement in multisensory perception research. The first study will demonstrate how people can flexibly integrate an SSASy to perform tasks requiring rapid, precise, and time-restricted body movements. The following presentation will address the direct manipulation of the cause-effect link between movement and spatial orientation, studying the mutual influence of head-trunk movements. The third presentation will investigate the impact of free walking relative to the gait cycle on audiovisual synchrony tasks and saccades. In the following presentation, the authors will focus on the role of exercise (running) in decoding the perception of time. The last presentation will investigate the use of the continuous tracking technique for studying the multisensory spatial integration process. All of these presentations address a wide variety of topics in the perceptual field. Still, they are united by the need to explore the association between perception and the active experience of it. By investigating how people dynamically interact with their surroundings and integrate sensory inputs with purposeful actions, these studies contribute to a more comprehensive understanding of perception within a multisensory framework and unravel the complexities of active perception and its implications for a nuanced comprehension of human perceptual processes in diverse contexts.

#1: Sensory augmentation in an active multisensory environment

James Negen **1, Heather Slater 2, & Marko Nardini 2**
1 Liverpool John Moores University & 2 Durham University

Sensory substitution and augmentation systems (SSASy) seek to either replace or enhance existing sensory skills by providing a new route to access information about the world. The unfortunate truth is that many clever SSASys have been engineered yet there is still low user acceptance. One possible route forward is to focus more on designing and evaluating SSASys in an active multisensory environment. This underexplored possibility could be a better training ground and could provide a more useful evaluation. I will briefly present some preliminary studies moving towards this goal. The main focus will be a recent study that tested the use of a basic SSASy to play a stripped-down version of air hockey in virtual reality with motion controls (Oculus Touch). Participants were trained for one hour to use a simple audio cue for the puck's location. They were tested on ability to strike an oncoming puck with the SASSy, degraded vision, or both. Participants coordinated vision and the SSASy to strike the target with their hand more consistently than with the best single cue alone. This acts as a proof of concept that people can flexibly integrate a SSASy to do tasks that require tightly timed, precise, and rapid body movements. Further, since unisensory performance was quite poor but the integration benefit was very consistent, it demonstrates the potential insights from multisensory testing. Studies in active multisensory environments may be a route forward to both better training and better testing for SSASys.

#2: Investigating the link between head and trunk movements and spatial orientation abilities in VR

Davide Esposito **& Monica Gori**
Istituto Italiano di Tecnologia

Spatial orientation is a complex ability that emerges from the interaction of multiple perceptual and motor cues. The head-trunk system holds a pivotal role in it, as in ecological conditions the head movements determine space perception and are determined according to the perceived space. However, the dynamics of such mutual influence is still unclear. To study it, VR can help substantially, as it enables the direct manipulation of the cause-effect link between movement and perceptual change with unprecedented ease and flexibility. This talk aims to present two VR applications that exploit such manipulation in alternative ways: SALLO and VRCR. SALLO is a Unity package for the psychophysical assessments of spatial orientation in VR. It contains tools to design psychophysical tasks; moreover, it simplifies the stimuli positioning and offers tools to guide the participants' body movements without physical restraints. VRCR is a first person-perspective archery-like serious game which aims to disentangle the motor control of head and trunk, their coordination, and their cause-effect link with perception by changing ad hoc the effects of head and trunk movements on the virtual space. VRCR has been used to investigate to what extent an alteration of the head-related action perception link affects the ability to hit a target, and SALLO has been used to frame the performance obtained in the VRCR in the realm of classical psychophysics. These results tighten the gap between passive and active perception and provide some insight into the generalizability of psychophysical procedures to contexts that are less controlled.

#3: Walking entrains saccade behaviour and modulates audiovisual synchrony perception

David Alais, **Gabriel Clouston, & Matthew Davidson**
The University of Sydney

Recent studies in our lab have examined perception and behaviour during locomotion. Using virtual reality head-mounted displays (HMDs) to present visual and auditory stimuli to free-walking participants, we present sequences of randomly timed stimuli as they walk. Using the HMD's head-height data stream we plot the timing of each stimulus relative to the gait cycle. After several hundred trials, we obtain a dense sampling of responses across gait phase and can bin the data to test whether performance is constant over the gait cycle or is modulated by the action of walking. Our results show clear cyclic modulations of perception (visual, auditory, audiovisual) and behaviour (saccades, manual responses). These modulations are sinusoidal, locked in phase to the gait cycle, and occur at the step rate (approximately 2 steps per second). Concerning saccades, we have shown that saccade likelihood during walking is modulated at the step rate, with incidence increasing at footfall and decreasing during the swing phase between footfalls (i.e., 1 cycle per step). This result shows an entrainment to action, which is also evident when we compare natural walking speed with slow walking. In a task designed to elicit rapid saccades, saccade rates are lower when participants walk slowly. In an audiovisual synchrony task, we show the temporal binding window changes depending on walk speed, being narrower for natural walking and broader for slow walking. Together these results show a previously unknown perception-action interaction that modulates and entrains perception and behaviour.

#4: The effect of running on visual and auditory time perception

Roberto Arrighi, **Irene Petrizzo, Eleonora Chelli, Tommaso Bartoloni, & Giovanni Anobile**
University of Florence

Amongst the factors that have been reported to be able to distort the perception of time, physical activity is one of the most debated as a full comprehension of the role of exercise on the encoding of time has not been achieved yet. Here, by leveraging on a time generalization task we investigated the effect of vigorous running on a treadmill on visual and auditory stimuli in the millisecond (0.2–0.8 s) and second range (1–4 s). Our results indicate that running induced a similar perceived expansion in vision and audition (distortions magnitude about 5-10%) but these effects were likely to tap on multiple, independent mechanisms. Indeed, perceptual biases induced by running in the two temporal regimes were uncorrelated. More, sensory precision (Weber fraction) levels were different for visual and auditory stimuli as well as for stimuli in sub- and second range. Overall, our study supports the idea that the human brain is equipped with multiple time mechanisms but also suggest that physical activity is capable of affecting all of them via generalized and shared resources.

#5: Continuous tracking of audiovisual stimuli

Alessia Tonelli **1,2, David Burr 1,3, & David Alais 1**
1 The University of Sydney, 2 Istitutito Italiano di Tecnologia, & 3 University of Florence

Research into multisensory processing is an important tool for studying and understanding typical and atypical development. However, one limitation when testing clinical populations is that traditional paradigms involve numerous conditions and many trials, making sessions long and tedious, which can lead to unreliable data. Recently, a new technique called "continuous tracking" has been introduced, which can often assess perceptual thresholds in a shorter time, and with a more enjoyable task. This technique seems particularly suitable for investigating audio-visual integration in space. We tested its effectiveness by asking participants to track for 1 minute an audiovisual stimulus moving in a random walk. As in traditional psychophysical experiments, the stimulus could be visual, auditory, or audio-visual. In the latter case, we had a congruent condition where the acoustic and visual stimulus followed the same random walk and an incongruent condition where there was a spatiotemporal shift between the visual and acoustic walk so that either vision or audition led the walk by a given time. We further modulated the reliability of the visual stimulus by blurring and masking to attempt to shift the weight more toward the acoustic stimulus. The results were less encouraging than we expected. Although both auditory and visual tasks could be performed quite well separately, there was very little audio-visual integration, even with degraded vision and attention directed to audio. We expect the reason was that auditory motion perception is very weak compared with vision, an impediment to integration.

#6: Contrast sensitivity depends on locomotor phase

Brian Székely **& Paul MacNeilage**
University of Nevada, Reno

Visual contrast sensitivity has traditionally been studied in stationary observers. During locomotion, maintenance of high-acuity vision involves reflexive head and eye movements to stabilize visual targets on the retina, typically limiting retinal slip velocities to less than 5 deg/s. Here we measured contrast sensitivity during walking while also measuring head, eye, and leg movements to better understand the impact of locomotor periodicity and associated motor and multisensory signals. Participants judged the orientation (+/-45 deg) of briefly presented Gabor targets against a gray background while walking or standing. Despite induced retinal image slip during locomotion, contrast sensitivity remained similar between walking and standing. When the contrast sensitivity judgments were binned according to stride cycle timing, the worst sensitivity was observed around the time of heel strike, likely due to the high retinal slip, with better sensitivity observed during other phases, indicating modulation of sensitivity as a function of locomotor stride cycle timing. These results provide insight into the mechanisms governing the dynamics of contrast sensitivity during locomotion.

Symposium Four

June 18 from 3:30 - 5:00 p.m. in DMSC 110

Symposium Organizers: Sarah Marchand and Alexandra Séverac-Cauquil

Unravelling the Neural Mechanisms of Multisensory Self-Motion Processing: From Primate Models to Clinical Applications

Self-motion processing, wherein individuals estimate their own position and movement through a combination of visual, vestibular, and somaesthetic cues is crucial for navigating and orienting oneself in space. This symposium dives into the neural substrates underlying this multisensory integration process, with a particular emphasis on visual and vestibular modalities. First, we will consider what is learned concerning the cortical areas involved in visuo-vestibular integrating from invasive approaches in nonhuman primates. Then, we will take a close look at the regions involved in this phenomenon in humans, and how they are solicited to shape a coherent representation of self-motion. Using cutting-edge stimulation and brain imaging methods, we will compare the cortical networks involved between human and non-human primates, with the aim of questioning the relevance of the non-human primate models. To go further in defining the key regions in these processes, the specialization and role of areas within this visuovestibular cortical network will be debated. Then we will look at how this research helps us to better understand the functioning of cognitive actions linked to locomotion or spatial exploration in everyday life, leading to clinical applications such as training potentially helpful in the context of pathologies impairing navigation and balance. Overall, we will show that by bridging insights from non-human primate models to human cognition, the research effort in this field paves the way for emerging clinical applications aiming at improving sensory processing and spatial orientation in individuals with sensory-related disorders.

#1: Spatial and temporal congruency of vestibular and visual signals in nonhuman primates for self-motion perception

Yong Gu
Chinese Academy of Sciences

Robust perception of self-motion (heading), during locomotion or spatial navigation requires integration of multiple sensory cues, including vestibular and optic flow. Neurophysiological studies have revealed that multisensory heading signals are prevalent in numerous brain regions (e.g, MSTd, VIP, VPS, 7a, V6, PCC, and more), providing potential basis for multisensory integration. However, the two modality signals frequently exhibit spatial, as well as temporal incongruence on single neurons, generating challenges for multisensory integration efficiency. To understand exact functions of vestibular and visual signals in different brain regions, we combine psychophysics, neural recording and manipulation on awake, behaving macaque monkeys when performing various tasks. Our data reveal that on one hand, neurons in sensory-motor association areas, including posterior parietal cortex, frontal cortex, and striatum process and accumulate sensory information with different dynamics, in particular, vestibular acceleration and visual speed, suggesting that the brain uses a temporal-incongruent model for perceptual decision making across heading cues. On the other hand, neurons in more sensory areas including extrastriate visual cortex, and posterior insular cortex, frequently encode conflict spatial directions. These findings suggest that multisensory information in the brain may not always be coded in a spatial and temporal congruent way. Rather, the misalignment may benefit perception or flexible tasks under more complex contexts that involve speed-accuracy tradeoff, self- vs. object-motion recognition, and more.

#2: Area V6 in human and non-human primates: a critical hub in the dorsal visual stream for visual motion processing

***Annalisa Bosco*, Michela Gamberini, Claudio Galletti, & Patrizia Fattori**
University of Bologna

In human and non-human primate brain, the prestriate visual area V6 is retinotopically organized and represents the entire contralateral visual hemifield up to the very far periphery. Area V6 is highly sensitive to visual motion, to the speed and direction of stimulus movement, and to the optic flow. V6 receives input directly from V1, and visual information from V6 follows two different paths: a lateral one towards MT/V5 (which represents the strongest cortical connection of V6) and other areas of the extrastriate visual cortex (MST, V3A, V4T, LIPv), and a medial one towards visuomotor areas of the superior parietal lobule (V6A, MIP, VIP). Given the particular properties of V6 cells, it was suggested that V6 is involved in the recognition of both object-motion and self-motion. In V6, self-motion signals can be "subtracted out" by the plethora of visual signals evoked by self-motion, so allowing to recognize object motion. Several imaging experiments supported this view also in humans. Furthermore, recent fMRI human studies have demonstrated that area V6 is particularly responsive to forward visual motion, suggesting its involvement in visual analysis of the environment toward which the person is moving during locomotion. Here, we will discuss the role of area V6 in visual motion processing in human and non-human primates, highlighting the differences with other motion areas of the dorsal visual stream. We will also discuss how V6 involvement in the perception of self-motion evoked by locomotion could have clinical implications in neurological diseases.
Funding: PRIN2022 n. 2022BK2NPS, MNESYS n. PE0000006.

#3: How crucial is V6 for self-motion cortical processing in human and non-human primates?

***Sarah Marchand*, Vanessa De Castro, Elisabeth Excoffier, Maxime Rosito, Nathalie Vayssiere, Jean-Baptiste Durand, & Alexandra Severac Cauquil**
Université Toulouse III-Paul Sabatier

The perception of self-motion involves several sensory modalities, two of them being the visual system and the vestibular system, whose physiological interaction is tight. Their cooperation allows the brain to build a coherent percept, ensuring efficient movements in space. Among the regions solicited by stimuli compatible with self-motion in these two modalities in humans, V6 area presents unique characteristics. By coupling functional magnetic resonance imaging (fMRI), visual stimulation and galvanic vestibular stimulation (GVS) in humans we explored the characteristics of the V6 activations regarding the axis of simulated self-motion (lateral or anteroposterior), and the congruence or not of visual and vestibular signals. We found that V6, in humans, is a region specialized in the perception of self-motion in the anteroposterior axis, and more specifically, in the movement that is most ecological to our species: forward motion. We also show that V6 is positively sensitive to the congruence of visual and vestibular signals. Building on these conclusions, we now explore the role of V6 in arboreal non-human primates (macaque monkeys) – which therefore naturally move in the three planes of space. Our aim is to assess whether there are specificities linked to the mode of locomotion among primates and the relevance of macaque monkey model to study the cortical control of self-motion in humans. Funding: ANR 21-CE37-0023

#4: Multisensory integration in egomotion-related visual areas

Sabrina Pitzalis
University of Rome "Foro Italico"

Complex behaviors such as grasping and walking in naturalistic conditions, require sensorimotor integration processes. During the last twenty years, several studies in human and non-human primates have investigated the neural bases of the sensorimotor integration processes underlying complex behaviors performed by upper and lower limbs. Human neuroimaging studies have revealed multiple cortical areas responding to egomotion-compatible optic flow stimuli (MT+, MST, V6+, V3A, VIP, pCI, CSv, PIC) and located in occipital, temporal, parietal, cingulate and insular cortices (Cardin and Smith, 2010). Recently, it has been investigated not only the visual role of these egomotion regions (i.e., by testing their sensitivity to different visual motion parameters), but also the possible motor role that these regions might have in the visually guidance of movements of lower and upper limbs during walking. Results from these fMRI studies revealed that three egomotion areas in cingulate and insular cortices (CSv, pCi, PIC) and two leg related somatomotor areas in the precuneus (hPEc and hPE) respond to both optic flow and long-range leg movements and are involved in multisensory integration processes, likely to guide/adjust leg movements during locomotion and heading changes (e.g., Serra et al., 2019; Di Marco et al., 2021). Results demonstrate a gradient of functional specialization and cortical connections from the human POs to the anterior precuneus, with more posterior regions dedicated to the analysis of visual attributes useful for spatial navigation, and more anterior regions devoted to integrate visual and somatic spatial information from both limbs, relevant for goal-directed action, as reaching and locomotion.

#5: The anterior-medial vestibular-visual network in humans

***Mark W. Greenlee*, Markus Becker, Sebastian M. Frank, & Anton L. Beer**
University of Regensburg

Self-motion perception involves an interaction between vestibular and visual brain regions. Lateral cortical regions include the parietoinsular vestibular cortex (PIVC/OP2) and the posterior insular cortex (PIC/VPS) forming a hub for a posterior-lateral self-motion network. In the medial cortex, the cingulate sulcus visual (CSv) area has been shown to be relevant for integrating visual and vestibular cues for the control of locomotion. A recent functional magnetic resonance imaging (fMRI) study conducted in our group showed that the vestibular-visual network in the medial cortex of humans not only includes area CSv, the V6 complex, and the precuneus motion (PcM) area, but also an area in the pericallosal sulcus (vPCS) that is strongly responsive to vestibular stimulation but not to visual and thermal stimulation and a visual motion area in the retrosplenial complex (mRSC) that exhibited activation in response to radial visual motion but not to vestibular and thermal cues. Here, we discuss the possible role of this extended anteriormedial vestibular-visual network in humans in the context of a dual pathway framework of vestibular-visual processing. We propose that the medial cortex areas are primarily involved in active self-motion perception, body stability, and spatial navigation. By contrast, the lateral cortical areas seem to be part of a posterior-lateral network that is primarily involved in passive self-motion perception, perceptual stability, and precise coordination of self-motion and action. Funding: DFG, Project GR988/25-1

#6: Egocentric navigation network plasticity: Training extends functional connectivity of V6 to frontal areas of congenitally blind people

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

Retinotopically organized visual area 6 (V6) processes optic flow in animals and humans. We previously demonstrated that V6 is a sensory independent area involved in egocentric navigation. Indeed, V6 of congenitally blind (CB) people encodes auditory input for egocentric navigation similarly to the way V6 of sighted people encodes visual cues. In the current study, rest functional connectivity was used to investigate training induced brain connectivity changes in CB participants. CB participants were scanned during resting state sessions before and after a three-day training period learning to navigate in mazes using the EyeCane, a sensory substitution device (SSD). Before training, functionally defined area V6 is connected with areas of the dorsal network while it is anticorrelated with mediotemporal areas, suggesting a 'division' between egocentric and allocentric spatial reference frames. After training however, V6 extends its connectivity to areas of the dorsolateral prefrontal cortex (9-46d) and anterior cingulate (24pr). These newly established connections may underlie the long-term plasticity observed in area V6 for processing auditory navigation cues, potentially reflecting the adaptation following training with the EyeCane and facilitating the acquisition of maze navigation skills. Our findings demonstrate that training can alter connectivity and induce long term plasticity in the dorsal stream. Since frontal areas are strongly involved in higher-order cognitive processes and in active control of planned behavior, results suggest that training the dorsal stream could be explored as a potential strategy to mitigate cognitive decline, especially for Alzheimer research since degeneration affects mainly the navigation network until reaching frontal areas.

Symposium Five
(invited)

June 19 from 11:15 a.m. - 12:30 p.m. in Timberline

Symposium Organizer: Aaron Seitz

Processes of Multisensory Learning

In this symposium, we highlight research addressing multisensory learning. Shams will first review the research on the malleability of binding tendency, discussing the experimental approaches shown to modify it, the potential learning mechanisms at play, the neural underpinnings of this tendency, and the pressing questions yet to be answered. Nardini and Scheller will present empirical data assessing the abilities of children and adults to learn to combine sensory cues for improving perceptual precision, suggesting that multisensory learning/integration may take place at different processing levels. Beierholm will illustrate how Bayesian models with mixture distributions can provide a powerful framework for understanding multisensory adaptation and learning. Newell will present findings from studies investigating how category representations are formed based on audio-visual information which suggest that category learning and adaptability to novel exemplars may be uniquely constrained in multisensory contexts. Seitz will present data regarding how multisensory information facilitate both perceptual learning and working memory training. Together we conclude that unraveling the mechanisms underlying multisensory integration promises meaningful clinical and practical benefits to people across the lifespan.

#1: How can the tendency to integrate the senses be modified?

Ladan Shams
University of California, Los Angeles

Sensory inputs are corrupted by various noises, and therefore, even when they arise from the same source, there is generally a discrepancy among the signals. This creates a challenge for the perceptual system in discerning whether two signals originate from one or separate sources. This decision is significantly swayed by the pre-existing expectation of a single source, dubbed as the "binding tendency." This tendency, the predisposition to integrate multisensory stimuli, can be the result of learning or hard-wired biases. Notably, research has revealed that this tendency is neither uniform nor static even for a given task; it varies among individuals and can fluctuate within an individual over time. I will review the research on the malleability of binding tendency, discussing the experimental approaches shown to modify it, the potential learning mechanisms at play, the neural underpinnings of this tendency, and the pressing questions yet to be answered. Unraveling the mechanisms and strategies to enhance binding tendency promise meaningful clinical and practical benefits, particularly for populations with challenges in multisensory integration.

#2: Learning to combine cues during childhood development and beyond

Marko Nardini & Meike Scheller
Durham University

Statistically optimal cue combination is a common finding in adult multisensory perception. However, the origins of this finely-honed process remain unclear. Presumably, it was learned during development, but the mechanisms underlying this learning are not yet understood. To address this, we look at how humans learn to use and combine cues. Studies assessing children's abilities to improve precision by combining cues consistently show deviations from optimal, or even beneficial, performance in children under 8-10 years. Studying how cue combination develops in adults using newly learned sensory cues provides another way of understanding how cue combination is learned. As in childhood, experience with specific cues is limited, but other child-adult differences, including maturation and other kinds of experience, predict that outcomes could be different. Adult cue combination studies with novel cues have shown mixed results, including clear cases in which some adults combine cues after only very short experience. From these developmental differences and variations across individuals, we argue that the computations leading to behaviour meeting cue combination model predictions can take place at multiple levels – from deliberate and effortful decision-making to relatively automatic sensory processing. New research using carefully directed multi-method approaches, combining psychophysical, neuroimaging and interview techniques, is allowing to probe more closely the different levels at which combination and learning may take place. This work points the way towards a new understanding of how efficient multisensory perception is learned, and can be reshaped, at different ages.

#3: Perceptual learning and adaptation with Bayesian mixture models

Ulrik Beierholm
Durham University

Learning and adaptation are essential processes that enable organisms to acquire and maintain perceptual senses that are well-suited to their environment. While these mechanisms are sometimes viewed as separate entities, they can both be understood as part of statistical inference and are direct extensions of Bayesian inference. In this talk I will explore how Bayesian models that assume mixture distributions, which directly follows from any attempt at inferring causal structures, can be used to explain phenomena in adaptation and learning. This includes perfect adaptation (when the perceptual system completely adjusts to a change in the environment), partial adaptation (when the perceptual system only partially adjusts to a change in the environment), and even repulsion (when the perceptual system responds in the opposite direction of a change in the environment). Additionally, this framework provides a natural way to understand how the perceptual system learns new associations. Through uni-sensory and multi-sensory examples I will illustrate how Bayesian models with mixture distributions can provide a powerful framework for understanding adaptation and learning. This framework is also consistent with classical and instrumental learning paradigms and can be used to explain a wide range of perceptual phenomena.

#4: How adaptable are object categories formed from multisensory inputs?

Fiona Newell **1,2, Alan O' Dowd 1, & Rebecca Hirst 1**
1 Trinity College & 2 New York University Abu Dhabi

Despite the complex, multisensory nature of the environment, the brain organises sensory information into categories that readily adapt to novel inputs. As such, category formation is likely based on all relevant sensory inputs although it is unclear how this is achieved. For instance, statistical regularities across modalities may facilitate category learning, or categories may be shaped by the reliability of each sensory dimension. We designed experiments based on novel objects defined by visual (spatial frequency) and auditory (pitch) dimensions to test these questions. In our first study, we examined whether corresponding audio-visual dimensions influence category formation. Participants initially learned to categorise exemplars based on each unimodal dimension independently (e.g., high spatial frequency= category A; low spatial frequency= Category B etc.). Then, separate groups were required to categorise combined audio-visual exemplars in which the optimal category structure was a disjunctive rule based on either corresponding (e.g. high spatial frequency and high pitch=category A) or non-corresponding AV dimensions. We found a benefit for categorising AV exemplars that were predicted from learned (unimodal) dimensions. However, adaptability to novel AV exemplars was lowest following learning of corresponding relative to non-corresponding unisensory dimensions. In a separate study we manipulated the underlying statistics of category dimensions. We report rapid adaptations suggesting that rule abstraction facilitated categorisation despite changes in the statistical properties of stimuli. Overall, however, the optimal disjunctive rule was not consistently deployed across participants. Our findings suggest that cross-modal category representations are flexible, however, category learning may be uniquely constrained in multisensory contexts.

#5: Multisensory Facilitation of Perceptual Learning and Working Memory Training

Aaron Seitz
Northeastern University

Perceptual learning and working memory training approaches are increasingly utilized for perceptual and cognitive rehabilitation. However, challenges to translation of these approaches is that training can be slow and often fails to generalize to untrained contexts. Multiple models suggest that multisensory presentation for stimuli can support faster learning the can transfer more broadly to untrained contexts. For example, models suggest that multisensory facilitation can arise through cross-sensory connections between unisensory representations and/or feedback to unisensory representations supporting stronger encoding in those regions as well as by modification or formation of multisensory representations, so that later presentation of unisensory stimuli activates an expanded, multisensory network of brain regions. In this talk, I'll discuss research of how multisensory cue combination can benefit both perceptual learning and working memory training. I'll discuss the broad implications of this research in the development of more effective interventions to promote perceptual and cognitive rehabilitation.

Symposium Six

June 19 from 1:30 - 2:45 p.m. in Timberline

Symposium Organizer: Monica Gori

Multisensory Development in Humans from Birth through Young Adulthood

This symposium will focus on a new research consortium structured to examine multisensory development in humans from birth through young adulthood. The MELD (Multisensory Environments to study Longitudinal Development) consortium will take advantage of recent technological advances in order to ask and answer developmental questions in mixed reality immersive environments, and in which experiments are structured in an effort to examine development using more naturalistic stimulus scenarios. In addition to collecting behavioral, perceptual and psychophysical data, high-density EEG will be collected on each child. The major theoretical framework for the work is a maturational sequence beginning with sensory segregation, followed by the development of multisensory integration and finally by the maturation of causal inference. This sequence is predicted to be associated with the back-to-front maturation of brain regions beginning with sensory cortices and ending with prefrontal cortex. Major elements of the consortium, which will be focuses of the individual presentations, include: the creation of immersive environments (Wallace), a coding framework for stimulus control and data acquisition (Watson), the use of generative AI enabled stimulus sets (Tovar), the development of novel haptic solutions (Gori), and the ability to capture high-resolution kinematic data regarding eye, head and body movements (Favre).

#1: Immersive Environments for Studying Multisensory Development

Mark T. Wallace
Vanderbilt University

Much of sensory and perceptual research is carried out under highly controlled laboratory settings. A great deal has been learned taking this approach, but it must be acknowledged that such settings fail to capture the complexity and dynamism of real world scenarios. Technological advances now allow these issues to be at least partly circumvented, by enabling the creation of immersive environments that not only better emulate the real world, but that also allow rigorous control over stimulus characteristics. In multisensory research, such environments thus allow not only for the presentation of complex naturalistic multisensory (e.g., visual, auditory, tactile/haptic) combinations, but also such combinations in which stimulus features such as spatial and temporal correspondence are altered. In addition, these immersive environments allow stimulus combinations that are targets for action/perception to be delivered within complex backgrounds. Finally, with state-of-the-art motion capture systems built into these environments, it is possible to not only monitor a variety of sensorimotor actions (e.g., eye, head and body movements), but also to deliver stimuli in contingent fashion. The talk will highlight the consortium's efforts in designing immersive mixed reality environments, specifically designed to answer fundamental questions regarding the development of multisensory processes in children, and the neural correlates of these maturational processes.

#2: Tools to develop, control, and analyze dynamic, immersive multisensory experiments

Marcus R. Watson
York University

The MELD consortium aims to move beyond the traditional static tasks, with impoverished stimuli and very limited possibilities for action, that have constituted most research in the neurosciences. Our goal is to immerse participants in a dynamic multisensory world, and collect a wide range of physiological, neurological, and behavioural data as they interact with these constantly changing environments. However such active experiments are harder to develop, control, and analyze than traditional static ones. In particular, ensuring the temporal reliability of simultaneous visual, auditory, and haptic stimulus delivery presents unique challenges, as does syncing multimodal stimulus events with the dependent measures collected from participants. In my talk, I outline the software tools and pipelines we use to develop MELD's experiments, to control them in realtime and coordinate the range of stimulus presentation and data collection hardware required, and to make sense of the results, and describe some of the remaining challenges faced by anyone interested in performing such research.

#3: Generative AI and cognitive science: Unifying sensory modalities in latent spaces

David Tovar
Vanderbilt University

The integration of sensory modalities into a unified latent space is a critical area of interest in cognitive science and artificial intelligence (AI). In cognitive science, the concept of a latent space in the brain refers to an abstract multidimensional space where various sensory inputs are integrated and processed to form a cohesive percept. In artificial intelligence, transformer models utilize attention mechanisms to weigh and integrate information from an input sequence, whether it be text, audio, or pixels, into a high-dimensional latent space. In this talk, we will review ways in which we have bridged the gap between these disciplines. Specifically, we will discuss ways in which 1) We have aligned and fine-tuned the latent spaces of AI generative models with experimentally derived latent brain dimensions and 2) Used generative AI to create multimodal stimuli that we can use as probes into the brain's latent space. In future studies, we plan to explore the developmental aspects of sensory integration across different age groups, focusing on how latent space dynamics evolve from childhood through adulthood. Furthermore, we intend to enhance and diversify our multimodal stimuli to comprehensively represent the range of objects encountered in daily life and to develop age-specific stimuli that reflect the maturation of sensory systems.

#4: Haptic development and multisensory processing: Basic science and technology

Monica Gori
Italian Institute of Technology

Haptic perception involves how we feel things through touch and movement, using sensors in our skin and kinesthetic receptors. It can happen passively, where we don't control it, or actively, when we do. While most research has focused on how we perceive sounds and sights, virtual reality now allows for more realistic experiences by adding technology that lets users feel sensations like touch and force. The renewed interest in understanding haptic perception in recent years might provide critical input to understanding haptic perception and to improve haptic technology in adults and in child developing systems. In the past years, we have investigated the development of haptic and tactile perception and their integration with other sensory modalities in children and adults with and without impairment. Our works, for example, show that before 12 years, the noise in haptic perception during active movements doubled compared to passive ones, and this motor noise might alter precision improvement. We also delineated the importance of haptic perception in developing visual size estimation and visual-haptic integration. In this talk, I'll show our recent results, the state of the art of haptic development, and the technologies available to study haptic perception and integration. I'll also present some haptic applications we have developed in the past years and demonstrate their use in scientific studies and applications.

#5: Human movement biomechanics: How can we get inspiration from other disciplines?

Julien Favre
University of Lausanne

Recording and analysing body movement have been of primary interest for a long time in several fields, including orthopaedics, rehabilitation, and sport sciences. Over the years, diverse devices and methods have been developed, bringing new possibilities, but also rising awareness on their limitations. This presentation will review common challenges associated with the quantification of human movement during daily-life activities and in high-resolution. For example, the advantages and drawbacks of usual recording devices, from inertial sensors to markerless motion capture, will be discussed from the viewpoint of studying multisensory development. Reliability, as well as features extraction and data reduction, will also be addressed. Finally, light will be shed on the challenges and promises of capturing human movement in naturalistic settings using mixed-reality technology. While some movement data could be obtained quite easily, identifying and collecting relevant measures could require more thought. Using concrete examples from a variety of domains, this talk aims to highlight points of particular attention in human movement quantification and expose strategies that have been deployed so far as well as solutions that could be expected in the future.

Symposium Seven
(invited)

June 19 from 3:15 - 4:15 p.m. in Timberline

Symposium Organizer: Jennifer Hoy

Multisensory Processing in Mouse and Insect Models

Successful multisensory integration underlies a myriad of adaptive natural behaviors. As such, the fundamental mechanisms underlying multisensory processing are likely to be highly conserved and may be investigated in precise detail in animal models. This symposium will showcase recent work in fruit flies, mouse and ecological models that have outlined the principal logic and neural circuits that underlie successful multisensory integration in the context of natural foraging behaviors.

#1: Multisensory enhancement of prey pursuit behavior in mice

Jennifer Hoy
University of Nevada, Reno

Across species, multisensory integration (MSI) is used to accurately and rapidly localize objects in the environment. This process is presumed to rely on the correct organization of sensory inputs into topographically aligned maps of egocentric space. However, this idea has not been rigorously tested. We show that mice improve their ability to hunt and capture live insect prey under ambiguous sensory conditions when they can both see and hear. As seen at the behavioral level, multisensory integration provides a mechanism for the mouse to enhance the representation of salient objects in the environment. We can thus exploit this ability to identify whether it depends on map formation and alignment of spatial information in the midbrain, or, whether behaviorally relevant spatial information is computed and accessed via a distinct neural circuit wiring mechanism. We can thus probe this system to uncover a clearer mechanistic understanding of how experience shapes auditory and visual integration in the mammal.

#2: Topographic alignment of auditory and visual receptive fields in the mouse superior colliculius

David Feldheim
University of California, Santa Cruz

Determining the location of an object in a complex environment and evaluating its saliency is a fundamental and necessary brain function. To achieve this, the brain needs to receive, process, and integrate sensory information from multiple sensory modalities. A model to study spatial sensory integration is the superior colliculus (SC). The SC receives and integrates auditory, visual and somatosensory input to direct the eyes and head to orient to egocentric and head-centered locations in the environment. In the primate and cat, spatial maps of vision and hearing are aligned in the adult SC, and individual bimodal neurons have overlapping visual and auditory spatial receptive fields (RFs). This same topographic alignment of visual-auditory RFs in the barn owl is sensitive to sensory experience during specific developmental phases and is linked to changes in orienting behavior. We aim to develop the mouse SC as a model to identify the molecular and activity- dependent mechanisms used align and integrate spatial information. We and others have shown that a combination of graded molecular cues and activity-dependent refinement is used to create the point-to-point map of visual space in the superficial layers of the SC; however, it remains unknown how the computed auditory map of space in the mammalian SC forms, and how this map becomes aligned and integrated with the visual map. In this talk I will share our recent work that demonstrates that the mouse SC contains aligned visual and auditory maps of space and our current progress towards determining how they form.

#3: A framework for modeling active multisensory integration

Ben Cellini, **Burak Boyacioglu, S. David Stupski, & Floris van Breugel**
University of Nevada, Reno

Vertebrates and invertebrates alike refine and combine sensory cues in the brain to estimate critical egocentric and allocentric information, such as their orientation in the world or the location of an external object. However, an animal's own motion can influence the quality of incoming sensory information. For instance, peering head movements appear to improve distance-to-prey estimation in mantises. We present a general framework to model how such active movements affect the quality of estimation tasks. We focus primarily on the case where sensory cues from multiple modalities must be integrated to estimate an unknown piece of information. Our approach leverages novel empirical observability tools and the Cramér–Rao bound from estimation theory to reveal what motor actions facilitate multisensory integration. As an example, we focus on anemosensing (estimation of ambient wind direction/magnitude) in flying insects. We show that there are two primary active sensing motifs that may enhance an insect's ability to navigate upwind: 1) rapid changes in course direction or heading angle and 2) rapid acceleration or deceleration. Our findings show that real trajectories of flies in a wind tunnel are consistent with these motifs. Altogether, our results provide insights into insect flight strategies and provide a framework for understanding a variety of sensorimotor behaviors.

#4: Visual and acoustic integration in mosquito swarms: Strategy for finding mates while avoiding collisions

Saumya Gupta **& Jeffrey A. Riffell**
University of Washington

Locating a friend in crowded settings like a busy restaurant or a packed music concert is a common challenge we often overcome by integrating visual and acoustic cues. Many animals also face similar challenges, needing to identify and locate targets such as potential mates or offspring, within their own dense social groups. Several species of mosquitoes, for instance, mate in aerial aggregations known as swarms, where they must find a mating partner among hundreds to thousands of other flying mosquitoes. Previous research indicates that male mosquitoes primarily use acoustic cues from the wingbeats of females to locate potential mates. However, navigating the complex aerial environment of a swarm – avoiding collisions with other males while pursuing the few females present – might require additional sensory strategies. We investigated whether Anopheles coluzzii mosquitoes, major vectors of malaria- causing pathogens in Africa, integrate visual and acoustic cues of flying mosquitoes for effective navigation during mate pursuit. In a virtual reality arena with tethered mosquitoes, we found that the sound of a female attracted males toward visual simulations of nearby mosquitoes. Additionally, we discovered that mosquitoes adjusted their wing kinematics to visual objects independently of acoustic cues, a behavior paralleling collision avoidance in free-flying mosquitoes within swarms. These findings suggest that mosquitoes can integrate visual and acoustic cues to locate mates while avoiding collisions, thereby advancing our understanding of the critical role of multisensory integration in target identification within complex social environments.

Symposium Eight

June 20 from 10:00 - 11:15 a.m. in DMSC 110

Symposium Organizers: Catherine Agathos and Haydée García-Lázaro

Shifting Sensory Reliance: Adaptive Strategies in Vision Impairment and Blindness

This symposium will explore adaptive strategies employed by individuals with partial or total vision loss to compensate for deficits in visual processing and perception. Presentations will cover a range of visual impairments, from induced stereopsis loss to central visual field loss, to blindness, considering also age-related changes, given that older adults show deficits in multisensory integration, but also rely more on multimodal information for accurate perception. Speakers will demonstrate how those with such impairments leverage spared vision, cross-modal plasticity, and perceptual learning to improve functional abilities. Adrien Chopin will show that removing stereopsis impacts older adults more than younger adults, suggesting a greater reliance on stereoscopic depth cues. Catherine Agathos will present changes in sensory reweighting in age-related central visual field loss, and how these relate to fall risk, while Jade Guenot will demonstrate the efficacy of combined electrical brain stimulation and perceptual learning in this population. Santani Teng will showcase how Braille reading patterns in blind people relate to reading expertise and efficiency, and Haydée Garcia-Lazaro will present the neural mechanisms allowing expert blind echolocators to rapidly integrate echo cues for localization. Taken together, these studies highlight the brain's adaptability and capacity to creatively employ a range of compensation techniques following vision loss, from leveraging spared vision to sensory substitution and enhancement via alternative modalities like hearing and touch to honing perceptual expertise through extensive training. Elucidating these adaptive strategies has important implications for developing customized interventions to improve functional abilities and quality of life in diverse populations with various degrees of visual impairment. The talks will be followed by a panel discussion with all speakers.

#1: Does losing stereoscopic vision matter? Age-related differences in cue combination compensation

Adrien Chopin **1,2, Diana Rdeini 1,3, Catherine Agathos 2, Chiara Ciucci 1,4 Yuling Wang 1, Valérie Parmentier 5, Denis Sheynikhovich 1, & Angelo Arleo 1,5**

1 Sorbonne Université, 2 The Smith-Kettlewell Eye Research Institute, 3 Université Paris Cité, Pisa University, & 4 Center Innovation & Technologies Europe

Our sense of depth is critical for everyday tasks and stereopsis (stereoscopic vision) is crucial for perceiving depth. Multiple visual cues (like stereopsis or motion parallax) are combined with proprioceptive cues (e.g., during vergence) into a single depth representation. Moreover, stereopsis is calibrated to individuals' peripersonal (action) space to optimize interaction with the external world. What happens when we lose stereopsis or when it weakens with age? This study explores how younger and older adults adapt to losing stereopsis in everyday life. Sixteen younger and 16 older adults with healthy stereopsis were asked to perform everyday tasks (making coffee, setting a table) under binocular and monocular (i.e., removing stereopsis) viewing while their movements were tracked. For fair comparison, we equalized the visual field between conditions, thus only manipulating stereopsis. The order of conditions was counterbalanced in each group. Primary outcomes were completion time and hand movement kinematics. We adjusted statistics for multiple comparisons. Removing stereopsis slowed down both age groups. Older adults were significantly more affected, taking significantly longer to finish each task. Albeit small, the effect suggests that older adults may rely more on stereopsis in daily life, or have greater difficulty compensating for its loss with other cues. Participants moved their hands faster when using stereopsis but we found no difference in smoothness. Age-specific interventions targeting stereovision (particularly as it is impaired in multiple age-related visual pathologies), multisensory integration or cue-combination could be valuable in improving autonomy and quality of life in aging.

#2: Sensory reweighting in central visual field loss

***Catherine Agathos*, Anca Velisar, & Natela Shanidze**

The Smith-Kettlewell Eye Research Institute

Aging leads to vestibular deficits that contribute to older adults' visual field dependence for perception and postural control. These age-related vestibular changes, combined with vision loss and oculomotor changes, may explain the higher fall risk and mobility issues of individuals with age-related central visual field loss (CFL). In a first study, we examined whether the age-related increase in visual field dependence persists despite CFL, or whether a reweighting occurs to leverage vestibular and somatosensory cues. Using a subjective visual vertical task, adapted for individuals with CFL, we tested older adults with monocular and binocular CFL and age-matched controls. We indeed observed that visual field dependence persisted in the CFL groups, despite reduced/less reliable vision. Additionally, those with binocular loss were significantly more visual field dependent than control participants, likely due to the spared peripheral retina. These findings are important when considering appropriate mobility rehabilitation and aids for this population given the association between visual field dependence and fall risk. Indeed, those who upweight visual cues tend to be more fall-prone, in part due to changes in body coordination. Vestibular signals drive optimal head stabilization when moving. In a second study, we examined head stabilization via motion capture in individuals with CFL and controls during a functional mobility task, to assess whether vestibular input is appropriately leveraged in CFL. Results varied across individuals, with poorer vision correlating with reduced control (greater head accelerations). These findings suggest, again, issues of sensory reweighting that can be addressed via targeted training.

#3: Improving visual rehabilitation strategies in patients with macular degeneration by combining perceptual learning with tRNS

Giulio Contemori 1,2, Marcello Maniglia 3, *Jade Guénot* 4, Vincent Soler 2,5, Marta Cherubini 6,7, Benoit R. Cottereau 2,6, & Yves Trotter 2,6

1 University of Padova, 2 Université de Toulouse, 3 University of California, Riverside, 4 The Smith-Kettlewell Eye Research Institute, 5 Service d'Ophtalmologie Centre Hospitalier Universitaire de Toulouse, 6 Centre National de la Recherche Scientifique, & 7 University of Trento

Macular degeneration (MD) is the leading cause of legal blindness in people over 65 years old. This disease involves a progressive loss of central vision, forcing patients to rely on their residual peripheral vision to process their visual environment. In order to decrease their visual impairments, readaptation strategies such as perceptual learning (PL) have shown promising results in enhancing their residual visual functions. However, it requires prolonged training and evidence of generalization to untrained visual functions is limited. Recent studies suggest that combining transcranial random noise stimulation (tRNS) with PL produces faster and larger visual improvements in participants with normal vision. Thus, this approach might hold the key to improve PL effects in MD. To test this, two groups of MD participants were trained on a contrast detection task with (n = 5) or without (n = 7) concomitant occipital tRNS. The training consisted of a lateral masking paradigm in which the participant had to detect a central low contrast Gabor target. Transfer tasks, including contrast sensitivity, near and far visual acuity, and visual crowding, were measured at pre- , mid- and post-tests. Combining tRNS and perceptual learning led to greater improvements in the trained task, evidenced by a larger increment in contrast sensitivity and reduced inhibition at the shortest target to flankers' distance. The overall amount of transfer was similar between the two groups. These results suggest that coupling tRNS and perceptual learning has promising potential applications as a clinical rehabilitation strategy to improve vision in MD patients.

#4: Integrating across hands in bimanual braille reading

Santani Teng

The Smith-Kettlewell Eye Research Institute

Braille is a tactile text system of raised dots used by blind readers, typically by moving the fingers of one or both hands over the printed surface. Braille readers who use both hands deploy them in various styles characterized, in part, by the spatiotemporal relationship between reading hands: how much unique and shared text each hand covers, and how reading movements are coordinated. Here, we investigated the shared and distinct roles each hand plays during bimanual reading. Using a position tracking system, we analyzed the hand kinematics of bimanual readers as they read standardized text passages aloud. We used completion time and regressions (short movement reversals) from each hand as indices of reading performance and intermanual dependence. Participants with more distributed hand movement styles (e.g. scissors) tended to read faster than those with more concentrated hand movements (e.g. parallel or left marks style). Notably, scissors-style readers disproportionately displayed signs of "simultaneous disjoint reading" (SDR), in which the two hands read different parts of the text at the same time. The use of SDR suggests a "memory buffer" mechanism distinct from visual print or serial braille reading, as input acquired in parallel is sorted on the fly to reconstruct a serial text stream. Our results quantitatively support previous work suggesting that the ability to use independent hand movements may be an important factor in the development of efficient braille reading skills, potentially informing the training of braille reading by teachers of the visually impaired.

#5: Neural dynamics of human click-based echolocation

Haydée García-Lázaro & Santani Teng
The Smith-Kettlewell Eye Research Institute

Echolocation is an active sensing strategy that leverages spatial hearing to detect, localize and discriminate objects. Some blind individuals use echolocation to sense and navigate their surroundings, complementing other mobility methods. Tongue "clicks" are a common method to ensonify objects and interpret the resulting echoes. Expert blind echolocators outperform non-expert blind and sighted individuals in most echo-acoustic tasks and modulate their clicking pattern dynamically to improve perception. However, it is still unknown how echoacoustic information is integrated across multiple samples (clicks) and how single echoes are neurally represented. To address these questions, we recorded the brain activity of blind and sighted individuals using EEG while they performed an echoacoustic localization task. Participants listened to a train of 2, 5, 8, or 11 synthesized mouth clicks and spatialized echoes from a reflecting object located at ± 5° to ±25° from the midsagittal plane. Subjects indicated whether the echo reflector was located to the left or right of the center. Proficient blind echolocators outperform novice-sighted individuals, with lateralization thresholds decreasing linearly from 2- to 8-click trials. Non-expert sighted performed at chance, with no effect of echo eccentricity or click count. Notably, they performed similarly to proficient echolocators when the emitted click was largely attenuated or removed. In blind experts, the location of the echo was reliably decoded from the EEG response after only one click, and successive click-echo samples linearly sharpened echoacoustic representations until saturation. In novice-sighted controls, spatial information was unavailable during the first clicks. These results suggest that echolocation expertise likely relies on extracting echoes from other masking sounds and integrating them across samples.

INTERNATIONAL MULTISENSORY RESEARCH FORUM
RENO, NV | 2024

Talk Session One

June 17 from 12:15 - 1:45 p.m. in DMSC 110

Haptic/Tactile/Somatosensor

Moderator: Simon Watt

#1: The multisensory basis of speech uncovered by a novel speech-to-touch technology

Kasia Ciesla **1,2, Tomasz Wolak 2, & Amir Amedi 1**
1 Reichman University & 2 World Hearing Center

From early childhood, we learn to perceive speech as a multisensory signal. Extra visual information, such as lip reading and gestures, are particularly beneficial when speech is distorted or in background noise. Here we test whether tactile inputs on fingertips representing low-frequencies of speech, can have the same effect. We also investigate neuronal correlates of multisensory integration before and after a short audio-tactile speech comprehension training. Seventeen people with typical hearing participate in several test conditions of repeating vocoded sentences in noise. They also do the same tasks twice in a 3T MR scanner and participate in two resting-state sessions. We show significant improvement in both auditory and audio-tactile speech comprehension (mean group SNR drop of 10dB). With the task-fMRI and rsfMRI results combined, after training we demonstrate : a) decreased functional connectivity (FC) within the early visual system (V1), and between V1 and the auditory cortex, b) increased FC within the higher-order visual network, and between V1 and the left association sensory cortex (contralateral to the stimulated hand). Furthermore, audio-tactile speech processing, as compared to audio, shows increased FC between a parietal multisensory hub and various regions in the occipital and frontal brain. The results indicate that auditory speech can be successfully combined with tactile information, and the engaged brain networks possibly reflect automatic processes in challenging auditory contexts, such as lip/body observation, and spatial perception. The results point to the role of nurture in the development of functional specialisation. The set-up holds promise for rehabilitation of.

#2: Cross-modal tuning in early visual and somatosensory cortices

Stephanie Badde **1, Ilona Bloem 2, Jon Winawer 3, & Michael S. Landy 3**
1 Tufts University, 2 Netherlands Institute for Neuroscience, & 3 New York University

Conflicts between the senses shape our perception. We used functional magnetic resonance imaging to test whether exposure to spatially offset visual and tactile stimuli shifts population level spatial tuning in early visual and somatosensory cortices. Participants fixated the center of a sketched right hand. During visual stimulation, yellow circles expanding and contracting at 4 Hz were superimposed on one fingertip. Tactile stimuli were amplitude-modulated vibrations at the fingertips of the right hand, also pulsating at 4 Hz. Stimuli swept across the fingers, moving from one finger to the next every 4 s, in ascending or descending order. Visual and tactile stimuli were either presented in isolation or synchronously. Visual-tactile stimulus pairs were either always located at the same finger, or always located at adjacent fingers, with the visual stimulus shifted either towards the thumb or little finger. Population receptive field (PRF) mapping confirmed topographically organized neural populations tuned to tactile stimulation of one finger in somatosensory but not visual cortex, and vice versa for visual stimulation. Maps from unisensory stimulation agreed well with those from congruent tactile-visual stimulation. Visual-tactile spatial discrepancy resulted in a PRF shift in all participants. Shift direction was independent of sweep direction ruling out prediction of the upcoming stimulus as the source of the effect. Rather, PRFs in somatosensory cortex were shifted toward the neighboring finger, consistent with tuning for combined visual-haptic locations and vice versa in visual cortex. In sum, our results reveal cross-modal effects on population-level spatial tuning in early visual and somatosensory cortices.

#3: Population-level coding of multisensory frequency signals in human neocortex

Alix Macklin **1, Katherine Perks 2, Lingyan Wang 3, Marcia O'malley 1, & Jeffrey Yau 3**
1 Rice University, 2 University of Washington, & 3 Baylor College of Medicine

Humans perceive the frequency of environmental oscillations by audition (sound waves) and touch (mechanical vibrations). These senses also interact in temporal frequency perception. Although auditory and tactile signals have been shown to converge in overlapping neural populations in parietal and temporal cortex, the operations performed by these populations are unknown. Here, we determined how unisensory and multisensory frequency signals are distributed over cortical sensory hierarchies and what computations support multisensory processing. We used functional magnetic resonance imaging (fMRI) and measured fMRI BOLD responses in human participants experiencing vibrations only, sounds only, and audio-tactile stimulus combinations. First, we implemented a hierarchical clustering analysis to characterize unisensory and multisensory response profiles. These results revealed distinct response motifs that are distributed across auditory, somatosensory, and premotor regions in a manner consistent with hierarchical processing. We next implemented competing models to predict voxel level responses to the multisensory cues. Encoding and decoding analyses demonstrate that distinct computations account for multisensory responses in different cortical regions. Our collective results reveal the hierarchical nature of multisensory frequency representations in the human brain, which are linked to distinct computations.

#4: Visual influence on tactile detection and localization in the case of somatosensory damage

Anupama Nair **1 & Jared Medina 2**
1 University of Delaware & 2 Emory University

We examined how visual information influences tactile detection and localization in an individual (JN) with right somatosensory cortical damage and age-matched controls. Using a mirror box, we examined tactile detection by manipulating whether the actual hidden hand was touched (+T) with a near-threshold monofilament, whether she saw a touch at the same location (+V), and whether she saw the mirror reflection. On trials with only a seen touch (+V-T), she reported phantom tactile sensations on her own hand significantly more often versus when the mirror was covered. Likewise, on tactile-only trials (-V+T trials), vision also influenced performance as she reported feeling touch more often when the mirror was covered versus exposed. These results suggest that vision dominated JN's contralesional tactile perception, both generating phantom tactile percepts and suppressing real tactile percepts on this hand. In a tactile localization task without vision of the tactile stimuli, she showed gross mislocalization consistent with previously reported cases with similar lesions. However, when viewing touch, her localization improved dramatically. We next determined whether nonpredictive viewed touch influences localization in neurologically-intact individuals using the Tactile Quadrant Stimulation test. Using a suprathreshold monofilament, participants identified the quadrant touched on their hidden hand while viewing mirror-reflected touch in the same (or different) quadrant. Vision influenced localization responses when incongruent, increasing the overall number of mislocalizations and mislocalizations consistent with mirror-reflected touch, suggesting that visual information is encoded in tactile localization.
Our findings highlight the influence of vision on tactile processes under normal and increased tactile noise.

#5: Tactile search and visuo-haptic matching abilities in early brain-based visual impairment

Claire Manley, **Stephanie Badde, & Lotfi Merabet**
Harvard Medical School

Cerebral (cortical) visual impairment (CVI) is an early brain-based visual impairment associated with a complex profile of visual deficits, including striking difficulties with visual search. We tested whether these deficits extend to the haptic domain. In experiment 1 (a haptic feature search task), blindfolded participants explored a tactile array to detect the presence or absence of a raised horizontal line among raised vertical lines (2x2, 3x3, and 4x4 arrays). Overall, CVI participants' responses were less accurate and slower compared to typically sighted controls. Most importantly, the characteristic increase in reaction time with increasing set size was larger in CVI compared to controls (especially given absent targets). In experiment 2 (a visual-/haptic-haptic matching task), participants were presented with a haptic or visual cue representing a target shape they had to find in a bag containing 3, 5, or 7 distractor shapes. Overall, CVI participants were slower and slightly less accurate than controls in finding the target shape in both cue conditions, and both groups showed increasing reaction time and decreasing accuracy with increasing set size in both cue conditions. Most importantly, like controls, CVI participants performed similarly whether the target was indicated by a haptic or a visual cue. These results show that CVI individuals who experience problems in everyday tasks are unlikely to experience difficulties maintaining an abstract representation of a search target. Instead, CVI individuals exhibit increased difficulty discounting larger numbers of distracting stimuli even when the distractors are presented haptically.

#6: Investigating online movement guidance to visual and non-visual targets

Abdulrabba Sadiya, **Gerome Manson, & Jessica Facchini**
Queen's University

Prior work has explored the spatial and temporal characteristics of adjusting movements to visual tactile and somatosensory target positions. This experiment aimed to explore movement corrections across all three modalities. Twelve participants made reaching movements to an LED (visual target), a brush touching the non-reaching finger (tactile target), or the non-reaching finger (somatosensory target). On some trials the target was displaced either 3-cm away or toward the participant, prior to, or 200 ms following movement onset. Participants were instructed to adjust their trajectories towards the new target location. Overall, participants exhibited a larger magnitude of correction to somatosensory target perturbations, followed by tactile target perturbations. Participants also exhibited shorter correction latencies in the somatosensory than the vision and tactile conditions, with no differences between the vision and tactile conditions. These findings support previous work showing that moving the target hand (i.e., somatosensory target) yields earlier and larger corrections than moving to a visual or tactile target. This work provides evidence that corrections to non-visual targets may be different depending on the sensory modality used to detect changes in target location.

Talk Session Two

June 17 from 3:45 - 5:00 p.m. in DMSC 110

Modeling

Moderator: Mike Landy

#1: Violations of Bayesian and Poisson behaviors in six classes of multisensory and multimodal neurons

Vincent Billock

Naval Aerospace Medical Research Laboratory

Sensory neurons are thought to have Poisson-like firing rate behaviors; these Poisson behaviors have consequences for Bayesian models of multisensory cue combination. However, most studies were done in purely visual neurons and show interesting deviations from pure Poisson behavior – a Poisson neuron's mean firing rate should equal its firing rate variance, but variances generally differ substantially from means. We could call these neurons 'Poisson-like' if their means were strictly proportional to variances, but the correlation is usually below 0.8. Gur et al. (1997) modeled variances of purely visual neurons from several studies as power laws of their means, with exponents that range from 1.08 (nearly linear; nearly Poisson-like) to 1.21 (not so linear; not so Poisson-like). Here, we extend this analysis to six published sets of cortical (and superior colliculus) multisensory and multimodal cue-combining neurons (binocular, audio-visual, audiotactile, visual-tactile, visual-vestibular). Every neural class showed deviations from Poisson-like firing rates with power-law dependence of variances on means. Multisensory neurons thus behave much like unisensory neurons. More importantly, when multisensory neurons are reacting to multisensory cues, their variances are generally not below both unisensory variances, as would be predicted from Bayesian cue combination theory. This was true even for the subset of cortical neurons that behave like weighted averaging mechanisms and look as if they could be computing a Bayesian average. Moreover sensory cue combination in these neurons is better modeled by Schrödinger's nonlinear magnitude-weighted averaging rather than by Bayesian MLE averaging governed by inverse-variance weighting.

#2: Decentralized neural circuits implement Bayesian sampling of multisensory integration

Wenhao Zhang
The University of Texas Southwestern Medical Center

Multisensory integration in the brain has been mathematically formulated as a Bayesian inference process to infer the posterior of the common stimulus feature generating received multisensory inputs. However, how the Bayesian computation in multisensory processing is implemented by multisensory neural circuits is not well understood. Therefore, we build a recurrent multisensory neural circuit model to provide insight of the neural architecture and algorithm in multisensory processing. The proposed circuit model has a decentralized circuit architecture of several coupled multisensory brain areas, where each multisensory area is modeled as a ring network model of Poisson spiking neurons and receives a corresponding feedforward neural input from a sensory modality. In this way, the recurrent connections across multisensory areas convey the information from other sensory modalities. We found the decentralized multisensory circuit dynamics implements a stochastic Bayesian algorithm called sampling-based Bayesian inference to compute the stimulus posterior. At each time step, each multisensory area stochastically generates population spiking responses, which is effectively drawing a random multisensory stimulus sample from the multisensory stimulus posterior. And the coupling between multisensory areas stores an association prior describing the co-occurrence of multisensory stimuli. Eventually, the multisensory stimulus can be linearly readout from population spiking activities across multisensory areas over time.

#3: Modeling stationarity perception

Paul MacNeilage
University of Nevada, Reno

Head and eye movement relative to the stationary environment gives rise to reafferent visual motion signals, i.e. optic flow. Stationarity perception depends on a process whereby observed visual motion signals are compared with those that are expected based on predictions derived from motor efference and/or supplementary reafferent information such as vestibular signals. When the observed and expected visual motion signals match sufficiently well, the visual environment is perceived as stationary. When signals do not match, the visual environment is perceived to move, a phenomenon akin to oscillopsia. Here we explore modeling frameworks that may be applied to better understand how the nervous system compares observed and expected visual motion. The default signal detection model assumes comparison of two statistically independent estimates, predicted and observed visual motion, which may be subtracted from one another to obtain a difference estimate with mean equal to the difference of predicted/observed estimate means and variance equal to the sum of predicted/observed estimate variances. Alternatively, these estimates may not be statistically independent and/or the nervous system may employ a Bayesian prior expectation that predicted and observed signals will agree. Here we explore the space of modeling results that can be obtained within this framework and compare model outputs to a range of recent psychophysical results quantifying how stationarity perception depends on the characteristics of the visual scene as well as the nature of head and eye movements.

#4: A new stochastic model for the sound-induced flash illusion

Hans Colonius & Adele Diederich
Carl Von Ossietzky Universität Oldenburg

A substantial body of theoretical and empirical findings has accumulated regarding the sound-induced flash illusion (SIFI, Shams et al. 2001). One variant of SIFI involves the observation that pairing a single visual stimulus with multiple auditory stimuli results in the perceptual illusion of multiple visual stimuli (fission illusion). SIFI is commonly regarded as an indicator of the strength of multisensory integration (MI), with adherence to three fundamental MI principles: close temporal and, to a certain extent, spatial proximity and inverse effectiveness. The susceptibility to this illusion is influenced by various factors, including precise physical stimulus parameters, participants' expectations, attention, and membership in clinical or non-clinical populations. The most comprehensive modeling framework to date is Bayesian Causal Inference (BCI), which combines concepts such as the relative reliability of modalities, prior expectations of numerosity, and prior expectations of a common cause. In line with the widely accepted "temporal binding window" concept, the integration of auditory and visual stimuli is perceived when they occur within a specific time window. However, a formal stochastic mechanism for this concept has been absent. Here, we introduce a stochastic model based on the time-window-of-integration (TWIN) framework (Colonius and Diederich, 2004). It predicts the probability of SIFI occurrence as a function of the temporal and physical arrangement of stimuli, enabling the separation of stimulus effects from potential biases captured by the BCI approach. The model's predictions are tested against various empirical datasets, and variability of the window width parameter is associated with temporal resolution as indicated by neural alpha frequency oscillations.

#5: Vision and proprioception's influence on sensorimotor confidence during adaptation

Marissa Fassold & Michael Landy
New York University

Humans can adapt to large and sudden perturbations of sensory feedback. What multisensory and motor-execution cues are used to determine confidence in action success, and do the dynamics of confidence parallel those of ongoing sensorimotor adaptation? Participants made a slicing reach through a visual target with an unseen hand, followed by a continuous judgment of confidence in reach success. After the confidence response, visual feedback of hand position was shown at the same distance along the reach as the target. For the confidence judgment, participants adjusted the size of an arc centered on the target. Larger arcs reflected lower confidence. Points were awarded if the subsequent visual feedback was within the arc, and fewer points returned for larger arcs. This incentivized attentive reporting of confidence and minimizing feedback-target distance to maximize the score. A 20 deg rotation was applied to the feedback during the central 50 trials of a block (alternating CW/CCW across blocks). We used least-squares cross validation to compare four Bayesian-inference models of sensorimotor confidence using prospective cues (knowledge of motor noise and visual feedback from past performance), retrospective cues (proprioceptive measurements), or both sources of information integrated to maximize expected gain (an ideal observer) with additional parameters for learning and bias. All participants used proprioception to calculate sensorimotor confidence during motor adaptation in addition to prior information. Confidence recovered exponentially to pre-adaptation levels after the perturbation ended, but at a different rate than motor learning.

Talk Session Three

June 18 from 8:30 - 9:45 a.m. in DMSC 110

Audio-Visual

Moderator: Marko Nardini

#1: Visual responses across the macaque auditory cortical hierarchy

Chase Mackey **1, Monica O'connell 1,2, Troy Hackett 3, Charles Schroeder 1,4, & Yoshinao Kajikawa 1**

1 Nathan S. Kline Institute, 2 New York University School of Medicine, 3 Vanderbilt University Medical Center, & 4 Columbia University

In auditory cortex, visual responses and visual modulation of auditory responses have been shown in many different studies, but it's unclear 1) how this operates across the cortical microcircuit, 2) how the process unfolds over time, and 3) where the visual signals originate. Here we report neuronal activity in core and parabelt (PB) auditory cortices from macaque monkeys engaged in an audiovisual oddball task requiring the discrimination of faces and vocalizations. Site-wise examinations revealed modulation of multi-unit activity (MUA) in response to visual stimulation, characterized by a brief, early MUA spike (median onset: 46.5 ms, interquartile range (IQR): 30.3 ms; median peak: 160 ms, IQR: 81.8 ms), followed by MUA suppression (median onset: 153 ms, IQR: 15.5 ms; median peak: 232.3 ms, IQR: 25.5 ms) in core auditory cortex. The later suppressive event had clear current source density concomitants, while the earlier MUA spike did not. In PB, we observed an early MUA spike (median onset: 72.3 ms, IQR: 32 ms; mean peak: 131.5 ms, IQR: 49 ms) followed by MUA suppression (median onset: 159.5 ms, IQR: 22.3 ms; median peak: 219.3 ms, IQR: 35 ms) in response to visual stimulation. In combined audiovisual stimulation there was moderate reduction of auditory responses during the MUA suppression interval in both core and PB. These data suggest a common sequence of events, across the auditory cortical hierarchy, following visual stimulation: afferent spikes followed by synaptic inhibition mediated by local interneurons. Potential sources of visual input will be discussed.

#2: Modality switching (and the absence thereof) modulates the redundant signal effect

Kalvin Roberts, Ines Jentzsch, & Thomas Otto
University of St. Andrews

Responses to bimodal signals are faster than those to their unimodal constituents. This so-called redundant signal effect (RSE) is affected by modality switching, where changing modality in a random trial sequence causes a slowing of responses. Critically, while unimodal trials can follow full modality switches (e.g., an auditory following a visual signal), bimodal trials can follow only partial switches (e.g., an audiovisual following a visual signal). Thus, the effect of full modality switches on bimodal responses is unknown. Here, in addition to the standard instruction to detect any auditory or visual signals, we presented tactile target signals in the random trial sequence. Consequently, bi- and unimodal trials can follow full modality switches (e.g., an audiovisual following tactile signal). Our data show that modality switching modulates the RSE, including violations of Miller's bound, which is often interpreted as a benchmark result indicating multimodal processing interactions. We find larger violations occurring in full modality switch trials and smaller (but still present) ones in modality repetition trials. Interestingly, unlike their unimodal counterparts, bimodal responses are not (or only marginally) affected by full modality switches. Thus, the observed modulation of the RSE is largely driven by unimodal responses that are slowed due to modality switching. Therefore, understanding modality switching and its differential effect on uni- and bimodal responses will be key to fully understanding the processes underlying the RSE.

#3: Congruent visual information enhances phoneme selectivity in auditory cortex

Yike Li & David Brang
University of Michigan

Visual speech information, such as lipreading, facilitates spoken word recognition. The neural mechanisms that support audiovisual speech perception remain poorly understood. To address how visual speech affects phoneme processing in auditory areas, we used intracranial EEG (iEEG) signals recorded in epilepsy patients during an audiovisual speech perception task. Participants listened to audio recordings either in isolation or with matching video recordings. Speech stimuli were words composed of 4 initial phonemes (/b/, /g/, /d/, /f/) and balanced following vowels or diphones. To quantify the selectivity of information processing during speech perception in auditory cortex, high-gamma power was used to calculate a phoneme selectivity index (PSI) for each phoneme and each electrode. For each electrode, we derived a total PSI across phonemes to represent general sensitivity to phonemes, and used the distribution of PSI values across phoneme categories to measure the neural selectivity of phonemes. Preliminary analyses indicate that congruent visual speech improved phoneme selectivity in neuronal populations located in the superior temporal gyrus. Specifically, results showed that audiovisual relative to audio-only trials generated higher total PSI values as well as less uniform distributions across phoneme categories. These data support a model of speech processing in which congruent visual information enhances the acuity of phoneme representations in the auditory system during speech perception.

#4: Electrical stimulation of the superior temporal gyrus evokes rapid responses in visual cortex

Emily Cunningham & David Brang
University of Michigan

It is well-established that concurrent sounds modulate the perception of visual stimuli. However, even in the absence of concurrent visual stimulation, transient sounds can evoke rapid responses in visual cortex. There are multiple pathways through which such responses may be generated, and the extent to which these signals originate in subcortical vs. auditory cortical regions is still a matter of debate. Although both animal and psychophysical work are broadly consistent with a cortico-cortical route involving projections from early auditory to visual areas, direct causal evidence for/against cortical involvement in sound-evoked visual responses is limited. One way to obtain such evidence is to take advantage of intracranial EEG recordings from patients receiving direct electrical stimulation over the superior temporal gyrus (STG). Here we examine existing data from 18 such patients, each of whom also had occipital recording sites proximal to regions previously shown to exhibit preferential responses to sound (primary visual cortex, N = 3, and/or probable V5/hMT+, N = 18). Two individuals showed signs of early evoked peri-calcarine responses following STG stimulation, with initial deflections peaking between 20-30ms. More sustained responses emerged between 100-150ms. In nine individuals, STG stimulation also evoked responses in lateral occipital regions near probable V5/hMT+ (with earliest deflections generally emerging between 100-200ms). In both regions, crossmodal evoked responses were associated with changes in low- but not high-frequency (gamma-band) activity, consistent with feedback signal propagation. These data provide initial evidence that at least some portion of previously-reported sound-evoked visual responses may originate from auditory cortex.

Talk Session Four

June 19 from 9:45 - 11:00 a.m. in Timberline

Learning

Moderator: Micah Murray

#1: Multisensory training enhances comprehension and cortical processing of auditory speech in noise

Ansley Kunnath **1, Hannah Bertisch 2, René Gifford 3, & Mark Wallace 2**

1 Vanderbilt University School of Medicine 2 Vanderbilt University, & 3 Vanderbilt University Medical Center

Speech understanding is a complex phenomenon that involves the integration of audiovisual speech cues. A key aspect of this integration is the temporal structure of the auditory and visual cues. Audiovisual temporal acuity can be measured by the construct of the temporal binding window (TBW). The TBW can be narrowed through training using a simultaneity judgment (SJ) task, but the effects of audiovisual training on speech understanding and neuroplasticity remain unclear. A computerized training program designed to improve audiovisual temporal acuity was administered over three days. TBW size and word recognition were evaluated before and after training. We also evaluated changes in cortical activation patterns using functional near-infrared spectroscopy (fNIRS). Participants were randomized to receive either active training (N=10) or passive testing (N=10). Trained participants demonstrated significant improvements in TBW size (393 ms to 329 ms; p=0.038). Participants who completed testing-only had no significant TBW changes (416 ms to 473 ms; p=0.229). Whereas trained participants had a small improvement in auditory word recognition in noise, untrained participants demonstrated a significant decrease (p=0.037). Narrower TBW was associated with better auditory word recognition in noise after training (p=0.025). Additionally, audiovisual training altered the neural representation of auditory speech in the visual cortex. Altogether, we demonstrate that the benefits of audiovisual temporal training can transfer to unisensory speech comprehension and engender changes in cortical networks supporting speech processing. These findings highlight the malleability of multisensory temporal integration and its role in speech understanding, and may guide rehabilitation for individuals with sensory impairments.

#2: Learning to use new signals for efficient multisensory perception: a psychophysical, neuroimaging and phenomenological approach

Marko Nardini **1, Meike Scheller 1, Melissa Ramsay 1, Prins Nick 2, & Chris Allen 1**
1 Durham University & 2 The University of Mississippi

There is great interest in augmenting perceptual abilities using new technologies, but little is known about how new signals can integrate and cooperate with existing abilities . We describe new research on this problem uniquely combining three powerful methods: model-based psychophysics to understand changes in multisensory computations, MRI decoding to understand changes in neural representations, and a phenomenologically informed interview technique (Bitbol & Petitmengin, 2017) to characterise subjective experiences of augmented perception. We trained participants to use novel auditory (e.g. pitch) cues together with familiar visual cues such as stereo disparity to judge depth over a range of settings and training durations. Key signatures of efficient adoption (cue combination) of the new cue into multisensory perception are revealed by model-based psychophysics. We have also characterised individual participants in sufficient detail to statistically test hypotheses at the single participant level. This has revealed unexpected persistent individual differences across participants. Crucially, we argue that sensory decision-making with newly learned signals can show efficient integration psychophysically, yet be revealed by MRI decoding to depend on alternative (nonsensory) combination mechanisms, and by interviews to involve allocating attention to two cues separately and sequentially. In conclusion, there is considerable scope to augment multisensory perception. However, a multi-methods approach is needed to understand the locus of underlying changes and the accompanying experience of effort and attention. This provides key information for understanding perceptual flexibility and leveraging it to enhance human capabilities.

#3: Do sensations get encoded in memory before or after crossmodal integration?

Ladan Shams, **Carolyn Murray, & Xiaohan (Hannah) Guo**
University of California, Los Angeles

We are constantly inundated with sensory data—sights, sounds, touch, and more—that we absorb for memory recall. The hippocampus is known to be essential for linking these multisensory cues for memory storage, but the exact nature of how sensory inputs are encoded remains a mystery. Interactions between the senses are critical in shaping perception, altering the experience of each sensory input in quantitatively or even qualitatively. A key question is whether memory encodes the raw sensory data, the postintegration sensory fusion, or both (see figure). To explore this, we employed the McGurk Illusion, where conflicting audio and visual syllables create the perception of a third syllable. Our study tested participants' recognition of syllables from videos, including both congruent (same syllable in both audio and visual) and McGurk Illusion variants. Crucially, participants were tested on the unisensory auditory syllable from the McGurk stimuli as well as illusory syllable representing the fused audio-visual percept. When recalling the syllables, a majority of subjects (54.2%) recognized the fused illusion over the actual auditory syllable. A smaller group (20.8%) remembered the auditory input more, while 25.0% recalled both unisensory auditory and fused syllables equally. Individual variability in the results suggest varying styles of memory encoding across individuals, with some primarily encoding multisensory fused representations, some primarily encoding independent unisensory representations, and some both.

#4: Investigating cross-modal effects: Examining the relationship between auditory spatial training and visuospatial skills

Walter Setti, **Helene Vitali, Claudio Campus, Lorenzo Picinali, & Monica Gori**
Istituto Italiano di Tecnologia

Visuospatial and working memory (WM) abilities play a crucial role in performing daily tasks and engaging with the external environment. However, there is a need for more training programs focused on enhancing visuospatial skills, particularly in the acoustic sensory domain. Despite having valuable insights into spatial mechanisms in the visual modality, the exploration of multi-sensory aspects of WM has been limited by a lack of suitable technologies. This study introduces an innovative acoustic system based on 3D spatial audio technology. The primary objective was to investigate whether a training session with our acoustic version of the Corsi Block Tapping Task (CBTT), named Audio-Corsi, could impact mental rotation abilities in the visual domain. Fifty-four young adults participated, divided into a control and an experimental group. Performance was evaluated in terms of reaction times (RTs) for correct trials on a computer-based Mental Rotation Task, both before and after either 20 minutes of rest or underwent training with the Audio-Corsi. The results reveal a significant difference in the reduction of RTs between the two groups. This suggests that visuospatial skills can be trained and potentially enhanced through spatial memory trainings in alternative sensory modalities, such as audition. The technology and procedure we have devised and developed could be applicable in both clinical and experimental settings for studying and training high-level cognitive skills, within the auditory sensory modality. Consequently, the system here presented has the potential to aid individuals with visual impairments in improving their spatial memory abilities, affected by the absence of vision.

#5: Uncovering individual differences in multisensory perception with newly learned cues

Meike Scheller **1, Olaf Kristiansen 1, Melissa Ramsay 1, Chris Allen 1, Stacey Aston 1, Heather Slater 1, Annisha Attanayake 1, Emily Bambrough 1, Nick Prins 2, & Marko Nardini 1**
1 Durham University & 2 The University of Mississippi

Multisensory studies often examine performance benefits at the group level, which can mask substantial intra-individual differences. Here we show how a novel, participant-level analysis can uncover individual differences in multisensory processing. We tested adults' abilities to learn arbitrary, new sensory cues to environmental properties: auditory pitch together with binocular disparity to judge object depth, and visual line orientation together with haptic cues to judge weight. Using 2AFC methods, we established the degree of cue combination (bimodal precision benefit) as marker of novel cue learning, using different study designs: "Large-N" (N=60; N=30), short-term training (~1hr) studies, in which data were analyzed at the group level, and "small-N" (N=8, N=6) medium-term training (~10- 12hrs) studies, which used a novel approach (Prins, 2024) to establish credibility intervals for multisensory precision benefits at the individual-observer level. With minimal training, the large-N group-based analyses showed no significant multisensory benefit. There was, however, considerable individual variation, with around half of each sample benefiting. Individual-based analyses on the small-N studies confirmed this statistically: around half of each small group showed immediate significant multisensory benefits, while the other half did not. These individual differences mostly persisted throughout extended perceptual training. This same result pattern was present in studies across both feature domains: depth and weight. These findings suggest that perceptual systems can vary substantially in their malleability later in life and raise new questions about the sensory and cognitive processes underlying these differences. They also highlight the value of new methods for assessing individual differences in perceptual function.

Talk Session Five

June 20 from 8:30 - 9:45 a.m. in DMSC 110

Audio-Visual - Special Populations

Moderator: Lora Likova

#1: Cross-modally induced visual sensations in a completely blind individual resembles retinotopic mapping in the visual cortex

Jesse Breedlove, **Logan Dowdle, & Cheryl Olman**
University of Minnesota

Blind individuals sometimes report feeling as if they can see things that they sense are around them through non-visual modalities even though they are physically incapable of detecting them through retinal vision. We refer to this experience as non-optic sight (NOS), which we explore through NS, a woman who lost her eyesight to retinal degeneration and later developed visual perceptions of real and present objects triggered cross-modally through touch and proprioception (e.g., if she picks up a mug, she "sees" a mug). To test whether these images are mapped topographically within NS's brain, we designed 3D-printed tactile versions of retinotopic mapping stimuli which could be used to cross-modally trigger NOS within a 7T scanner. Every 8s, NS was cued to rotate a physical 3D wedge around a fixed point (16 positions) or shift a 3D bar up/down or left/right (18 positions). We performed population receptive field mapping using the resulting fMRI data. Receptive field parameters across NS's visual cortex showed a striking organization resembling typical retinotopy: increasing eccentricity moving anteriorly from the occipital pole and voxels tuned to portions of the visual field contralateral and flipped relative to their respective cortical locations. Fascinatingly, some phase reversals can even be observed occurring roughly at the anatomical locations where transitions between V1/2/3 are typically seen. These results represent the first topographic mapping of stimuli experienced as visual perceptions in a completely blind individual and demonstrates that the visual cortex can support concrete visual experiences that accurately interpret cross-modal sensory input in blindness.

#2: Characterizing audio-visual integration abilities in early brain-based visual impairment

Lotfi Merabet **1, Claire Manley 1, & Stephanie Badde 2**
1 Harvard Medical School & 2 Tufts University

Individuals with cerebral (cortical) visual impairment (CVI) may have lower-level visual functions that are largely unaffected. However, higher-level functions that require information integration often show severe impairments. Here, we tested whether CVI participants integrate visual and auditory stimuli. In the first experiment, participants detected visual or auditory stimuli presented either in isolation or simultaneously. Overall, CVI participants (n=5) responded slower than typically sighted controls (n=11), but both groups showed faster RTs for the combined compared to the unimodal presentation. While consistent with a multimodal redundancy gain, responses violating the race model were lower in the CVI group. Additionally, most CVI improved more than control participants when auditory and visual stimuli were blocked by modality rather than interleaved. In the second experiment, participants indicated the location of visual and auditory stimuli presented either uni- or bimodally. Both groups performed perfectly in the visual but not in the auditory condition. In the bimodal condition, auditory localization responses in both groups were attracted toward the location of the visual stimulus (ventriloquism). However, the effect was more pronounced in the CVI than control group, and only the CVI group showed a shift in visual localization toward the auditory stimulus. The effects in both groups varied with the distance between the stimuli in accordance with causal inference models of integration. Our results show that individuals with CVI can integrate simple auditory and visual stimuli. However, integration appears less optimal than in typically sighted controls.

#3: The multisensory nature of misophonia: Positive attributable visual sources reduce the impact of trigger sounds in misophonia

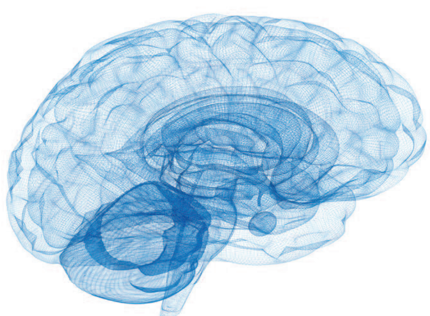
Ghazaleh Mahzouni, **Moorea Welch, Michael Young, Veda Reddy, & Nicolas Davidenko**
University of California, Santa Cruz

Misophonia (literally meaning hatred of sound) is a relatively new term that describes extreme psychological and physiological reactions to specific types of trigger sounds and associated stimuli (e.g., chewing, slurping, etc.). While misophonia has traditionally been characterized as an auditory disorder, recent findings suggest that high-level and multisensory factors also play a role (Samermit et al., 2022). In our current work, we investigated the role of positive attributable visual sources (PAVS) in modulating reactions to misophonic trigger sounds in people with misophonia. Participants (26 misophonia and 31 healthy controls) were presented with 26 short video clips: 13 misophonia trigger sounds (e.g., crunchy chewing) paired with the 13 original video sources (OVS; e.g., video of crunchy chewing) and the same trigger sounds paired with 13 PAVS (e.g., video of tearing a piece of paper). After each sound, participants rated the pleasantness and intensity of bodily sensations felt and described the nature of these sensations. Our results show that PAVS-paired sounds significantly increased ratings of pleasantness and reduced the intensity of bodily sensations in both misophonia and control participants, compared to OVS-paired sounds. Importantly, participants with misophonia showed significantly more reduction in the intensity of bodily sensations compared to control participants. Overall, our results show that misophonics' negative emotional and physical reactions to trigger sounds can be attenuated by presenting these sounds alongside positive attributable visual sources, which can potentially provide an avenue for developing novel interventions for misophonia.

#4: Assessing audiovisual speech perception in noisy environments: a functional near-infrared spectroscopy study on postlingually deafened adult cochlear implant users

Yi Yuan **1, Yingying Wang 2, Jeffrey Skidmore 1, Bailey Javidi 1, & Shuman He 1**
1 The Ohio State University & 2 University of Nebraska-Lincoln

Audiovisual (AV) speech perception benefits vary significantly among cochlear implant (CI) users, influenced by multiple factors (Stevenson et al., 2017). This study examined the relation between AV speech perception in noise and peripheral neural synchrony, as well as the association between AV speech perception in noise and cortical functional activation in postlingually deafened adult CI users. Methods: To date, ten subjects have been recruited and tested. All subjects received a CochlearTM Nucleus® implant in the test ear(s). Peripheral neural synchrony was assessed using the electrically evoked compound action potential (eCAP). Cortical activation was assessed using functional near-infrared spectroscopy (fNIRS) during the speech perception task. Sentence-level speech perception performance was evaluated in auditory-only, visual-only, and AV conditions with multi-talker babble noise. In visual-only and AV conditions, the target temporal envelopes were synchronized with the amplitude of a spherical shape, which served as visual stimuli. Results: Preliminary findings suggest that subjects with poorer peripheral neural synchrony tended to gain more benefits from audiovisual integration under +10 dB and +5 dB signal-to-noise (SNR) conditions, compared to those with better peripheral neural synchrony. Additionally, fNIRS results demonstrated variations in cortical activation patterns during audiovisual processing among subjects. Conclusion: Our findings highlight the intricate relation between peripheral and cortical processes in AV speech perception among CI users. These results call for further research to identify crucial factors accounting for individual differences, resulting in more effective rehabilitation strategies.



Talk Session Six

June 20 from11:30 - 12:45 p.m. in DMSC 110

Visual-Vestibular Interactions and Self-Motion

Moderator: Laurence Harris

#1: Studying precision and temporal dynamics of heading perception with continuous psychophysics

Björn Jörges, **Ambika Bansal, & Laurence Harris**

York University

It is a well-established finding that more informative optic flow (e.g., faster, denser, or presented in a larger portion of the visual field) yields increased precision in heading judgements. Current models of heading perception further predict faster processing under such circumstances, which has not been shown empirically. In this study, we validated a novel paradigm by replicating the effect of the speed and density of optic flow on precision, and investigated how these manipulations affected the temporal dynamics. To this end, we tested participants in a continuous psychophysics paradigm administered in Virtual Reality. Immersed in a starfield environment, participants experienced four 90-second blocks of optic flow in which their heading direction at any given moment was determined by a random walk. We asked them to continuously indicate with a joystick in which direction they were moving. In each of four blocks they experienced a different combination of simulated self-motion speeds (SLOW or FAST) and starfield density (SPARSE or DENSE). A Cross-Correlogram Analysis determined that more informative optic flow led to faster adjustments and a higher precision in responses. Modelling the data using a Kalman filter further showed that perceptual noise was, indeed, higher in conditions with less informative optic flow. Overall, we validated the use of continuous psychophysics as a useful tool for investigating heading perception and established that more informative optic flow can speed up this perceptual skill.

#2: Stationarity perception and VR sickness: Effects of repetition and rotation axis

Savannah Halow, *Val Rodriguez*, Eelke Folmer, & Paul MacNeilage
University of Nevada, Reno

Perception of a stationary visual environment depends on mechanisms that compare observed and expected visual scene motion that is generated when the head and/or eyes move relative to the visual environment. Here we seek to understand how stationarity perception differs depending on the axis of head rotation, how it changes across measurement on consecutive days, and whether there are associated changes in measures of VR sickness. The experiment was conducted with roll, pitch, and yaw head movements, ten subjects per condition. On each trial, participants wearing a head mounted display executed a head turn and judged whether the displayed scene motion was too slow or too fast. The gain on scene motion was manipulated across trials and a psychometric fit to the data yielded measures of precision (JND) and accuracy (PSE) of stationarity perception. VR sickness was quantified using questionnaires before and after each experimental block, yielding distinct sub-scores for nausea, oculomotor discomfort, etc. These measures were collected on 3 consecutive days to investigate whether perception and sickness improve with repeated exposure. Precision on stationarity judgements improved over consecutive days. However, contrary to expectations, an improvement in sickness over consecutive days was not consistently observed: different patterns were observed for different rotation axes. We relate differences across rotation axes to differences in visual and nonvisual stimulation across axes.

#3: Noise exposure and noise-induced hearing loss predicts visual dependence in the rod-and-frame task

***Christian Sinnott*, Catherine Agathos, Anca Velisar, & Natela Shanidze**
The Smith Kettlewell Eye Research Institute

Noise exposure (NE) is a global health issue and is associated with negative effects including hearing loss and potentially vestibular dysfunction. Previous work in non-human mammals demonstrates a robust relationship between acute and chronic noise exposure, vestibular insult, and sensorimotor deficits in activities reliant on vestibular information such as postural control. Analogous human work is lacking, as estimating one's lifetime noise exposure is difficult. Here, we assess lifetime noise exposure using participant interview and audiometry in 39 participants and investigate whether noise exposure affects verticality perception and sensory integration using the subjective visual vertical (SVV) and rod-and-frame (RFT) tasks. In our cohort, head tilt and frame presence biases judgment of upright towards the direction of head tilt and frame orientation in the SVV and RFT, and this phenomenon is affected by noise exposure. Using a series of multiple regression models, we show that self-reported noise exposure and audiometric estimates of noise-induced hearing loss are significantly predictive of how visual dependence (the extent to which verticality perception is biased by visual information in the RFT) evolves across the lifespan. We probe this finding further through constructing and fitting a Bayesian sensory integration model, which combines a head tilt prior with two likelihoods representing current visual and vestibular information in the SVV and RFT tasks. We hypothesize that increasing vestibular variability, or noise in the vestibular signal, will be associated with increases in self-reported noise exposure and audiometric indices of noise-induced hearing loss.

#4: The role of action control in self-motion perception under ambiguous situations

Anne-Laure Rineau **1, Lionel Bringoux 2, Jean-Christophe Sarrazin 1, & Bruno Berberian 1**
1 ONERA & 2 Institut des Sciences du Mouvement Etienne Jules Marey

Recent studies highlight a failure to consider the operator's active state when understanding self-motion perception, while visuo-vestibular integration research tend to concentrate on passive self-motion conditions. Such a question can be approached through the prism of agency since it refers to the fact that intentional control over actions and their consequences shapes perceptual experiences. In this context our two studies explore the impact of action control over self-motion perception. In the first experiment, participants discriminated between consecutive longitudinal movements under Passive (automatic) and Active (manual) conditions. The second experiment involved participants identifying synchronicity between physical and visual movements in these two same agency conditions. In addition, in each of these two agentive conditions, participants performed the tasks at two levels of intensity, which delimit two levels of ambiguity in the resolution of the requested tasks. The main result common to both studies is a deterioration in performance as ambiguity increases in the so-called Passive condition. This deterioration is mainly marked by a loss of discrimination sensitivity in this non-agentive condition (i.e., higher standard deviations of psychometric curves). Conversely, a resilience to ambiguity is shown in the Active condition, with stable discrimination sensitivity in this agentive condition when ambiguity increases. These results are also accompanied by greater confidence of participants in their own performance, or better metacognitive reliability. Active conditions were characterized by high predictability of the sensory consequences. Therefore, we hypothesize that top-down mechanisms engaged in the agentive condition induced lower prediction errors and may partly explain such promising results.

#5: Does the vestibular system affect time perception differently in different modalities?

Fatemeh Ghasemi & Laurence Harris
York University

The perception of time is altered in microgravity (Navarro Morales et al. Microgravity 9: 2023) but in such a complex environment it is hard to identify this as specifically vestibular-mediated. Here, we manipulated the reliability of the vestibular cue by varying posture and by applying disruptive galvanic vestibular stimulation (dGVS) while measuring perceived time duration. Participants (n=30 for each exp) judged whether a stimulus was longer or shorter than their personal estimate of 1s while lying and standing. In exp 1, participants judged the duration of an LED that was attached to stem protruding from a helmet and viewed at 50cm (so that it was at the same location as posture varied). In exp 2, they judged the duration of sounds (1,000hz) played through headphones. In exp 3, they judged the duration of a tactile vibration (200hz) delivered through tactors mounted on the backs of both hands. In exp 4, they judged visual duration with and without dGVS. There was no effect of posture on the estimation of 1s for auditory (771ms ± 69ms) or tactile stimuli (1,062ms ± 61ms). However, the perceived duration of 1s for the visual LED was 7% longer when lying (1,132ms ± 112ms) compared to when standing (1,068ms ± 104ms) (diff 64.6ms, p=0.005). Pilot data also suggested an increase under dGVS. Interestingly, the perception of 1s varied depending which modality was being judged. But only visual judgements were affected by posture suggesting specifically visual time perception may be influenced by the vestibular system.

Poster Session One

June 17 in DMSC Foyer

#1: A behavioural investigation of the effects of planning a foot action on the dynamics of the near-space representation

Gherri Elena, **Gioacchino Garofalo, & Alan O'Dowd**
University of Bologna

Recent studies have demonstrated that the representation of peri-personal space (PPS) can be strongly modulated by the intention to execute a spatially-directed hand-movement. However, the question of whether analogous motor-induced PPS modulations can be observed during the planning and execution of lower limbs movements remains almost completely unexplored. Here we investigated whether any changes in the visuo-tactile PPS map occur during the planning of an action with the foot. We asked participants to respond to the location of a tactile stimulus delivered to the finger (top) or the thumb (bottom) while a visual distractor, placed close to or further away from the foot, was presented at congruent or incongruent elevations (top or bottom). This version of the cross-modal congruency task was performed under two different experimental conditions, as a baseline task and embedded into a movement-planning task. In the baseline task, comparable cross-modal congruency effects (CCE) were present both near and far the foot. In the movement-planning task, the CCE near the foot shrank considerably, whereas it increased at far foot locations. These observations demonstrate that PPS is modulated by the intention to perform goal-directed foot movements. Our results possibly reflect the anticipatory strengthening of PPS representations of the space surrounding the movement goal at the expense of the currently occupied foot location when a movement is imminent. This data can be better understood in the context of locomotion, to which the lower-limbs are naturally attuned. Key words: PPS – Lower limbs – action planning – visuo-tactile representation.

#2: Exploring the intertrial priming of pop-out in touch: behavioural and electrophysiological evidence

Fabiola Fiorino, Cristina Iani, Sandro Rubichi, & *Gherri Elena*
University of Bologna

In mixed features search tasks, the feature defining the singleton target changes across trials. Typically, responses are faster when the target feature is repeated across successive trials compared to non-repetition trials. This effect, known as Intertrial Priming of Pop-Out (PoP), suggests that the efficiency to select and report perceptually salient singleton targets is modulated by the properties of the preceding search array. While PoP has been extensively investigated and debated in the visual domain, little is known about this effect in touch. To investigate the presence and characteristics of PoP in a tactile search task, we manipulated the repetition or alternation of the singleton target vibrotactile frequency across trials (either high frequency among low frequency distractors or vice-versa) and asked participants to localize the target presented among three homogeneous distractors. We recorded behavioural measures and event-related potentials (ERPs), specifically the N140cc component considered a marker of tactile selective attention, to uncover the mechanism underlying PoP in touch. The sequence of trials was manipulated so that on half the trials the singleton frequency was repeated, while on the other half it was alternated. In line with visual search studies, better performance for both RTs and accuracy was observed when the singleton target feature was repeated across trials than when it was alternated. Importantly, larger N140cc amplitudes were observed on repetition compared to alternation trials, demonstrating that the priming of pop-out effects emerged during the attentional selection of the target. Key-words: tactile search; selective attention; priming of pop out; event-related potentials.

#3: Audiovisual correspondence modulates the audiovisual temporal perception according to unisensory temporal sensitivity

Ruqin Li, Chenjie Dong, & Suiping Wang
South China Normal University

Temporal perception is a fundamental multisensory function critical for human survival and adaptation. Accurate temporal perception relies on the integration and segregation of multisensory temporal signals. While the role of sensory reliability on audiovisual temporal integration has been widely revealed, the effect of prior knowledge, such as audiovisual correspondence, remains unclear. In this psychophysical study, we examined the effect of audiovisual correspondence on temporal judgment using the Bouba - kiki effect. Twenty-two participants (15 female, aged 18 - 25) were asked to learn the correspondence between auditory (e.g., 'bou') and visual (e.g., round figure) stimuli. Then, they were presented with two Bouba -kiki stimuli in sequential order and reported which one was longer in 4 tasks (i.e., auditory, visual, audiovisual–report-auditory, and audiovisual-report-visual tasks). Additionally, the correspondence between auditory stimuli and visual stimuli (audiovisual correspondent and incorrespondent) was manipulated in the audiovisual tasks. Participants' responses were fitted with Gaussian cumulative curves, and the point of subject equality (PSE) and discrimination sensitivity (slope) were compared across tasks. The results showed that the temporal discrimination sensitivity was higher on the auditory task than on the visual task. Furthermore, significant interactions between audiovisual correspondence and reporting modality were found in the temporal discrimination sensitivity in audiovisual tasks. When reporting auditory temporal information, participants exhibited greater sensitivity to temporal interval changes in the audiovisual correspondent condition compared to the in-correspondent condition. These findings suggest that modulations of the prior knowledge on audiovisual temporal perception varied according to the sensitivity of unisensory temporal perception.

#4: Auditory and visual imagery support sensorimotor synchronization

Fang Jiang, Benjamin Sreenan, Canhuang Luo, & Simon Whitton
University of Nevada, Reno

Sensorimotor synchronization (SMS) governs motor coordination with rhythmic stimuli within daily multisensory experiences. Studies utilizing finger-tapping tasks demonstrate worse SMS consistency with visual cues than auditory or tactile, although including apparent motion in visual cues can enhance SMS consistency. Individual differences, such as heightened auditory imagery vividness, also play a role in bolstering visual SMS, emphasizing the multisensory nature of imagery. Using a fingertapping synchronization-continuation paradigm, our previous research revealed that individuals with higher auditory imagery vividness showed higher SMS consistency during continuation with no guiding visual cues. To further examine the importance of auditory imagery, we incorporated auditory and visual distractors during continuation and tested SMS performance in proficient imagers. While visual distractors exerted negligible influence, auditory distractors significantly compromised their SMS consistency. Electroencephalography (EEG) analysis revealed neural entrainment solely in the presence of distractors, suggesting that auditory or visual imagery was utilized to support SMS performance. Occipital neural entrainment during continuation with auditory distractors implied the involvement of visual imagery. Sub-vocal entrainment was another feature unique to SMS performance in the presence of auditory distractors. Despite employing a combination of neural and sub-vocal imagery strategies, SMS consistency with auditory distractors failed to reach the levels observed with visual or no distractors. Our findings underscore the strategic utilization of rhythmic imagery in one modality when imagery in another is limited, highlighting its multisensory nature.

#5: Brain networks involved in recognition memory are recruited more strongly, and more extensively, by real objects than by images of objects.

Grant Fairchild 1, Samantha Lee 1, Michael Compton 1, Desiree Holler 2, Sara Fabbri 3, Christian Nemeth 1, Lars Strother 1, & Jacqueline Walsh-Snow 1
1 University of Nevada, Reno, 2 University of Nevada, Las Vegas, & 3 Radboud University

Studies of human memory typically rely on two-dimensional (2-D) image stimuli. However, previous work has shown that images are less well-remembered than real objects, which offer many more multisensory cues than images do. Here, we used fMRI to examine the neural basis of this difference. During an initial learning phase, participants were shown a large set of everyday items presented either as real objects or as images. During a subsequent recognition phase in the MRI scanner, participants viewed words that corresponded to items that either had been presented, or had not been presented ("foils"), during the learning phase. Participants' task was to judge whether they had seen each item, and if so, whether the item had been a real object or an image. Univariate analyses found that cortical networks commonly implicated in recognition memory were activated more strongly for real objects than for images; no regions showed the opposite pattern. Next, a multivariate searchlight classifier revealed successful decoding of recognition memory for both real objects and images versus foils, but this decoding was considerably more widespread for real objects. Moreover, an additional multivariate analysis revealed that several regions, including the hippocampus and parahippocampal cortex, represented the format in which the stimulus was presented during the learning phase. Together, our results show that brain networks implicated in recognition memory are activated more strongly, and more extensively, by multisensory real objects than by image displays, and that areas within this network represent the format in which a previously viewed item was seen.

#6: Contribution of stimulus statistics to auditory, visual, and audiovisual motion perception in macaque monkeys

Adriana Schoenhaut 1, Ramnarayan Ramachandran 2, & Mark Wallace 1
1 Vanderbilt University & 2 Vanderbilt University Medical Center

Motion perception is a key aspect of sensory processing that enables animals to interact successfully with their environment. While extensive research exists on the psychophysical aspects of visual motion perception, little is known about how auditory and audiovisual motion are perceptually processed, particularly in non-human primates (NHP). NHP studies in particular offer a unique opportunity to link perceptual processes to underlying neural mechanisms. Our study aims to establish the foundation for future neurophysiological experiments by exploring how the perception of auditory, visual, and audiovisual motion changes with manipulations of different low-level stimulus characteristics in macaques. NHPs were trained to perform a 2-AFC task in which they judged the motion direction of auditory, visual and audiovisual dynamic motion stimuli (random dot kinematograms and auditory motion embedded in noise). We systematically manipulated stimulus parameters such as motion coherence and stimulus duration, velocity, and displacement to evaluate their respective influence on motion sensitivity. We found striking individual differences in the slopes of auditory and visual psychometric functions. The slope similarity of these functions depended on stimulus duration and velocity, and mediated whether or not behavioral benefits were seen to audiovisual combinations. Our findings illustrate how low-level stimulus statistics play an essential role in determining whether visual capture or multisensory gain are observed. To our knowledge, this study demonstrates the first concerted effort to characterize how parametric manipulations of auditory, visual and audiovisual ideal stimulus parameters impact motion perception in awake, behaving NHP.

#7: Effect of non-visual Cues on Spatial Navigation Abilities

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While vision is crucial for spatial navigation, the influence of non-visual sensory cues in this context remains a research subject. Using the SensFloor® system, this study explores how sighted individuals, when blindfolded, learn and recall simple and complex trajectories with either only proprioceptive or audio-proprioceptive cues. The findings reveal a significant enhancement in spatial recall when an acoustic stimulus, specifically white noise, is introduced during the learning phase. This study also illustrates the accuracy of the SensFloor® technology in extracting walking parameters, thus underscoring its applicability in both research and potentially clinical settings. Furthermore, this research presents a practical approach to enhance training programs, aiding individuals with vision impairments to achieve greater mobility and self-sufficiency by monitoring their walking through this realtime system.

#8: Effects of Motion Opponency on Standing Postural Sway

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Motion opponency, the cancellation of overlapping and opposing directional signals, is a fundamental aspect of motion processing models. This cancellation has been observed in both human behavioral and neuroimaging studies. Stimuli exhibiting locally balanced and opposing motion signals elicit suppressed global motion perception and reduced activation within area V5 in human observers. While the transient effect of unidirectional visual motion cues on standing postural sway has been well established in the literature, to our knowledge, the influence of motion opponency on standing postural sway has not been examined. In the current study, we test how standing postural sway is affected when viewing locally balanced and opposing motion signals across bidirectional motion opponent and non-opponent conditions. The bidirectional and motion-opponent counter-phase condition contains pairs of dots moving toward and away from one another along the horizontal plane. Due to motion opponency, this motion should yield no perception of global horizontal motion. The bidirectional and non-opponent in-phase condition contains pairs of dots moving in parallel, such that no local balancing is present, yielding a perception of global horizontal motion. Critically, both conditions contained equal numbers of opposing motion signals. This experiment examined whether perceptually cancelled motion signals can induce standing postural sway. We found that both motion conditions elicited increased standing postural sway relative to baseline conditions, suggesting that conscious perception of global motion may not be needed to influence standing postural sway.

#9: Efficacy and mechanisms of virtual reality treatment of phantom leg pain

Rand Williamson 1, Elisabetta Ambron 2, Brandon Knight 1, Maxim Karrenbach 3, Jing-Sheng Li 3, Eric Rombokas 3, Branch Coslett 2, & Laurel Buxbaum 1
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Approximately 90% of individuals with limb amputation experience a persistent sensation of the missing extremity, known as a phantom limb, and up to 85% experience debilitating pain in the missing limb, termed phantom limb pain (PLP). We previously demonstrated that Virtual Reality (VR) with active leg movements and vision of a virtual limb significantly reduces phantom limb pain in subjects with below the knee amputations. In this clinical trial, we are testing the efficacy and mechanisms of VR treatment of phantom leg pain. Individuals with lower limb amputation and PLP are randomly assigned to one of two 8 session VR treatments with either an active virtual leg or a commercially available VR pain treatment (REAL i-Series®) and asked to rate their PLP before and after each session. Using ultra-high resolution (7T) functional magnetic resonance imaging, precise somatosensory and motor maps of the limb are obtained at the beginning and at the end of the treatment to test for possible treatment-related changes in cortical representation of the lower limb. Our preliminary data show a beneficial effect of VR treatment for PLP, in particular for our active treatment, and advance our theoretical understanding of the mechanisms and functional neuroanatomy of PLP.

#10: Enhancing relaxation through multisensory meditation

Gizem Ozdemir, Adi Snir, Amir Amedi, Amber Maimon & Iddo Wald
Reichman University

Enhancing Relaxation through Multisensory Meditation This study explores the efficacy of enhancing traditional body scan meditation with immersive technologies, focusing on spatial audio and vibrotactile feedback, to improve relaxation and reduce anxiety. Utilizing a vibrotactile bed that provides tactile feedback at specific body locations, the research aimed to assess the effects of technology-enhanced meditation on anxiety, rumination, and relaxation levels. The experiment involved 44 healthy adults divided into three groups who experienced a 10-minute audio-guided body scan meditation with congruent vibration, non-congruent vibration, or no vibration. Anxiety levels were measured using the State-Trait Anxiety Inventory (STAI), rumination with the Brief State Rumination Inventory (BSRI), and relaxation states with the Relaxation State Questionnaire (RSQ). Statistical analysis showed a significant reduction in anxiety levels over time ($F=30.212$, $p<.001$) across all groups, with the congruent vibration group experiencing a notable decrease in anxiety ($MD=9.867$, $p=.004$). The non-congruent vibration group demonstrated a significant reduction in rumination ($MD=118.667$, $p=.041$). Relaxation scores indicated a significant improvement in the congruent vibration group ($MD=-0.693$, $p=.015$). The findings suggest that multisensory meditation with vibrotactile feedback significantly lowers anxiety levels, with congruent sensory feedback enhancing relaxation, and non-congruent feedback reducing rumination. These results highlight the potential of integrating congruent sensory feedback in meditation practices to deepen relaxation and suggest non-congruent sensory feedback as a novel therapeutic approach to managing rumination.

#11: Acoustic parameters underlying sound symbolism in real words and pseudowords: a machine learning approach

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Sound symbolism is related to the crossmodal correspondence in which word sounds are associated with non-auditory properties, such as shape (e.g., "knife" sounds pointed while "ball" sounds rounded). Recent work shows that sound symbolism in pseudowords (e.g., /kɛke/ sounds pointed, /molo/ sounds rounded) is associated with particular properties of the acoustic speech signal. Still, it is unclear if these effects generalize to real words. Here, we tested the hypothesis that the acoustic-to-ratings relationship found for pseudowords is similar to that in real words. Participants rated the sounds of real words (English nouns) and pseudowords on a "very rounded" to "very pointed" scale. The pseudowords included one set constructed from phonemes known to be strongly sound symbolic and another, more word-like, set constructed by replacing phonemes from the real words. Following prior work, we used the machine learning "K-nearest neighbors" algorithm to identify the combination of acoustic parameters that best predicted perceptual ratings. There was substantial overlap in the optimal parameter combinations for the pseudowords and the real words; moreover, the optimal parameter combinations for predicting pseudoword ratings performed well when predicting real word ratings. Multiple regressions were used to understand the contribution of each parameter to the predicted ratings for each stimulus set. Crucially, the regression coefficients for each pseudoword set were similar to the coefficients for the real words. Together, these results support the hypothesis that the relationships between sound-symbolic shape ratings and the acoustic speech signal are similar for real and pseudowords.

#12: Increased Audiovisual Integration in the Peripheral Visual Field: Modulation through Common Cause Weight in a Hierarchical Causal Inference Model

Yabo Zheng & Lihan Chen
Peking University

Recent behavioral and neuroimaging studies have demonstrated that observers' susceptibility to audiovisual integration varies as a function of the locations of visual stimuli across the visual field, in which the peripheral vision is believed to have a stronger tendency to bind with auditory input. Yet, current findings still lack systematic examination across a wide range of visual angles and a quantitative explanation of the computational mechanisms. Here, we employed the sound-induced flash illusion (SiFI) to investigate how the spatial characteristics of visual targets modulate audiovisual integration in the presence of accompanying auditory beeps. We presented visual flashes at nine locations across a large, 120° span of the visual field (ranging from 60° leftwards to 60° rightwards, with a 15° step size). We observed that the proportion of illusory reports (typically "double flash") increased with eccentricity, indicating an increased tendency for the peripheral visual field to be influenced by auditory events. To provide a unified account for the illusory reports, we developed a Hierarchical Causal Inference model and adjusted its parameters to probe the mechanisms underlying the spatial differences in integration susceptibility. Our findings suggest that the increased tendency for integration in peripheral vision is not due to uni-sensory uncertainty, but rather to the attributed weight of a common source signal during the integration process. These findings advance our understanding of the spatial constraints in audiovisual integration and highlight the intricate interplay between sensory modalities across different positions in the visual field.

#13: Interoceptive signals under virtual reality modulate pain processing

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1 Special Education College of Beijing Union University & 2 Peking University

Pain is a multifaceted subjective experience that is modulated by various sensory events, such as observing a virtual hand can modulate pain perception. Pain perception is also affected by interoception. However, the effects of the cycle of interoceptive signaling on pain remain controversial. This study aimed to examine how the interoceptive cycles in nearly realistic human body, affect the pain processing. We built a heartbeat enhanced virtual reality-based Rubber Hand Illusion (RHI) environment and manipulated the observers' sense of body ownership and the cardiac cycle. The body ownership illusion (BOI) was manipulated with RHI paradigm under virtual reality. The BOI was induced in the experimental group but not in the control group. The cardiac cycle included systolic and diastolic phases. Participants received pain stimulation under four conditions: BOIsystole, BOI-diastole, NoN-BOI-systole, NoN-BOI-diastole. Pain thresholds, intensity ratings, unpleasant ratings, and somatosensory evoked potentials (SEPs) were recorded. Compared to the systolic phase, participants reported lower ratings of pain and unpleasantness with reduced N1 and P2 amplitudes in diastole phase. The modulation of the heartbeat cycle on pain processing was not influenced by the BOI. Therefore, the cycle of interoception has modulated pain processing, which was independent of BOI. It suggested that pain perception could be finely modulated by the heartbeat cycle and heartbeat-enhanced virtual reality could be implemented in pain-related therapy.

#14: Metacognition in audiovisual spatial integration

Zinong Li, Luhe Li, & Michael Landy
New York University

Humans are often optimal in multisensory cue integration. Are humans also optimal Bayesian observers when reporting their confidence in multisensory estimates? Here, we explore how observers use varying uncertainty across different stages in the causal inference process to report confidence in audiovisual spatial estimation. The causal inference process involves three stages: observers make noisy auditory and visual location measurements corrupted by sensory noise, compute intermediate location estimates for common- and separate-cause scenarios, and derive a final estimate by averaging these intermediate estimates, weighted by the probability of the corresponding causal scenarios. We compared models that derive confidence based on the uncertainty at each stage of this process. An optimal observer bases confidence on the final percept's uncertainty, considering the discrepancy between estimates in common and separate causal scenarios. A suboptimal observer derives confidence from the uncertainty of the more probable intermediate estimate. A heuristic observer relies on sensory noise alone. These models make qualitatively different predictions for binary confidence reports, depending on cue discrepancy and reliability. We carried out an audiovisual spatial ventriloquist paradigm, varying the audiovisual spatial discrepancy and the reliability of visual stimuli. Participants were presented with a simultaneous audiovisual stimulus pair and received a post-cue to localize either the auditory or visual stimulus. Then, they reported whether they are confident or not about their location estimate. We found distinctive participants that align with the qualitative predictions of each model, suggesting individual differences in employing optimal and suboptimal strategies for confidence judgment in multisensory integration.

#15: Multisensory music perception: The role of internal state and auditory stimulation

Charlotte Kelly & Ladan Shams
University of California, Los Angeles

To experience music is a multisensory process. Those who play music integrate the tactile sensations of the instrument with the sounds they produce. Even music listeners at a concert experience auditory stimuli in a tactile way, through the powerful vibrations of loud speakers. These physical experiences can then lead to physiological responses in the body that inform music enjoyment. If auditory signals can entrain brain oscillations, what other physiological responses may result from music? The literature focuses on audition's effect on perception and emotion, but what about interoception?This study aims to find the relationship between music listening enjoyment and physiological responses, with a focus on heart rate, respiration rate, and electrodermal activation. We presented participants with previously unexperienced pieces of instrumental music and asked them to subjectively rate their resulting valence and arousal. We also recorded the participants physiological state using ECG, RSP, PPG, and EDA for the duration of each piece of music. We will discuss the relationship between internal state and external stimuli, and how this affects music enjoyment. By shifting our understanding of music listening to include physiological measurements, we seek to discover the role of internal state on the music listener and expand our multisensory understanding of music cognition.

#16: Effect of proprioception on footwear-related gait difference in older adults

Amy Morris, Fang Jiang, & Nicholas G. Murray
University of Nevada, Reno

Gait analysis is conducted without shoes or controlled for to reduce the variability of shoe type on gait metrics. Among older adults, walking with shoes compared to barefoot decreases cadence, increases step length, and minimally affects step width. However, there are mixed results with gait velocity. Given that proprioception, the sense of body movement and location, plays an important role in posture and gait control, it is likely that older adults' proprioceptive acuity could influence these footwear differences. The current study examined the impact proprioception has on footwear-related gait differences in older adults. Specifically, we quantified gait metrics (cadence, gait velocity, step length, and step width) in 16 older participants (70.69 ± 3.82 yrs.) during walking with shoes and while barefoot. We asked participants to wear whichever shoes they thought were most comfortable for their day-to-day errands. We measured proprioceptive acuity using joint position matching (JPM) and split the older participants into two groups based on their JPM error rates. The high-error group had significantly elevated JPM error compared to the low-error group. We found that shoes, compared to barefoot walking, significantly decreased cadence and increased gait velocity only in the high-error group. Further, shoes significantly increased step length for both the low- and high-error groups. There was no footwear difference in step width for either group. These results suggest that the footwear-related differences in gait previously found in older adults may depend on an individual's level of proprioception, specifically in cadence and gait velocity.

#17: "Just a Quick Game Please!": Improvements in Eye Movement Behavior While Reading Following a Brief Action Video Game Session

Hassan Naeem & Nicolas Davidenko
University of California, Santa Cruz

Adults and children with attention-deficit/hyperactivity disorder (ADHD) tend to show abnormal eye movements while reading, which can have consequences for reading performance. As a possible intervention for addressing this aspect of ADHD, the present study investigated whether playing an action video game (AVG) for 30 minutes could lead to subsequent changes in eye-movement behavior while reading. Twenty-three participants were recruited and assigned either to an AVG condition or a non-action video game (NAVG) condition. All participants read a passage of text while an eye tracker recorded their eye movements, both before (T1) and after (T2) playing the video game. Several eye movement metrics were assessed at T1 and T2, including: number of fixations, average fixation duration, proportion of regressions, proportion of left to right saccades, and overall reading rate. Additionally, reading comprehension measures were obtained by administering a quiz following each passage of text. Participants with low scores on the reading comprehension quizzes were excluded from the analysis. Results showed that participants who played the AVG had a significant reduction in fixation durations from T1 to T2, whereas participants who played the NAVG did not. No significant changes were observed in other measures of reading performance. These novel findings have implications for those with ADHD and related reading disorders, as AVGs can serve as a fun and engaging way for children and adults to train aspects of their reading skills.

#18: Vection, Presence, and Cybersickness in a Virtual Reality Driving Simulation

Benjamin Hughes, Hassan Naeem, & Nicolas Davidenko
University of California, Santa Cruz

Illusory self-motion (or "vection") in virtual reality (VR) environments is often accompanied by motion sickness (or "cybersickness"), limiting VR's accessibility. We investigated whether speed, posture, motion cue direction, and virtual reference frame influenced cybersickness, vection, and presence in a VR driverless car simulation presented on a head-mounted display. Experiment 1 presented 52 participants with 60- second laps generated in iRacing and manipulated speed (60mph vs. 120mph), body posture (upright or reclined by 30 degrees), and virtual reference frame (aligned or misaligned in pitch by 30 degrees with gravity), in a within-subjects design. Participants experienced eight laps around a virtual racetrack (one per condition, in counterbalanced order) and reported cybersickness, vection, and presence after each lap. Only speed had a significant effect on all measures ($Fs>15.0$, $ps<.01$): cybersickness, vection, and presence were all higher at high-speed. Posture interacted with real-virtual reference frame alignment such that vection was stronger when the virtual world aligned with the participants' head orientation. Experiment 2 manipulated driving speed and motion cueing direction (expanding, contracting, or translational). Participants ($N=36$) reported significantly more cybersickness and vection in the expanding (forward-facing) condition compared to the contracting (backward-facing) and translational (side-facing) conditions ($Fs>3.35$, $ps<.05$). Across experiments, participants' head-motion behavior during forward-facing and world-aligned conditions followed a normative pattern, with systematic head turns along the yaw axis in response to virtual turns. In Experiment 2, adherence to this pattern predicted vection strength in forward-facing conditions ($rs>.34$, $ps<.05$). Our results have implications for understanding cybersickness in VR.

#19: The influence of ocular counter roll from simulated head tilt on stereoacuity

Stephanie Reeves 1 & Jorge Otero-Millan 1, 2
1 University of California, Berkeley & 2 Johns Hopkins University

When humans tilt their heads towards the shoulder, the two eyes rotate around the lines of sight in the opposite direction of head tilt. This ocular counter roll (OCR) is driven by the otolith organs of the vestibular system and only partially compensates for head tilt. The torsion induced during OCR results in a misalignment of the horizontal meridians of the two eyes, which leads to binocular vertical disparities. The current work sought to investigate the effect of retinal image rotation due to simulated OCR on stereoacuity while sitting upright. To answer this research question, we recruited 8 participants to view stereoscopic random dot ring stimuli (spanning 2° to 3.5° peripherally, duration of 200 ms) with the use of a haploscope. Subjects reported whether a stimulus with disparities of ±0.1. 0.3, 0.5, 0.7, and 0.9 arcmins appeared in front or behind a fixation target. The stimulus rings were rotated by ±0°, 5°, 10°, and 30° to simulate OCR. Results revealed that stereoscopic thresholds during the 30° stimulus rotation were significantly worse than the 0° stimulus rotation thresholds ($t(7) = 3.00$, $p=0.02$). However, this decrement was not worse than what is predicted by the reduction in horizontal disparity alone ($p=0.31$). Thresholds from stimulus rotations of 0°, 5°, and 10°were not different from one another ($p>0.66$). These results indicate that the vestibular system may have been adapted to allow for precise binocular vision by limiting the amount of OCR to 10° or less, a tolerable amount of OCR for stereopsis.

#20: A dynamic model of multisensory processing

Miriam Reiner
Technion, Israel Institute of Technology

It has been well established by multiple studies that multisensory integration affects neural processing, leading to measurable effects such as response time and accuracy. The purpose of this study is to explore the pattern of effects. For instance, is the effect linear, e.g. will an additional cue, a third modality, change the response time by reducing the response time linearly? And what would be the pattern of multisensory effect with the addition of sensory cues with additional modalities? The purpose of this paper is to bring evidence showing that the brain processes multisensory cues according to the mathematical behavior of a complex system. We introduce here a mathematical model of multisensory integration, based on assumptions of a dynamics system, then test whether they fit results of multiple studies on the effect of multi/unisensory cues integration. We define synergetic and antagonistic interaction across sensory cues (referring to cues that increase rather than reduce the human response time) all supported by experimental data. We test additional effects, that are in essence similar to multisensory effect on reduction of response time and enhanced accuracy, such as emotional states that might be synergetic or antagonistic, then raise questions related to a ceiling effect – what is the enhancement, reduction maximum effect, i.e. what is the window of enhancement reduction in the brain capacity to respond to multisensory cues.

#21: Anomalous multisensory cortical excitability in Schizotypy

Wendy Torrens, Jenna Pablo, Michelle Ruiz, Rasia Yankaway, Marian Berryhill, & Sarah Haigh
University of Nevada, Reno

One of the most robust biomarkers in psychiatry is the sensory hypo-excitability seen in individuals with schizophrenia, especially to auditory stimuli, suggesting that they are less sensitive to incoming sensory information than non-clinical individuals. However, subclinical individuals exhibiting schizophrenia-like traits (schizotypy) report more illusions in the Pattern Glare Test (PGT), consistent with behavioral cortical hyperexcitability and being more sensitive to sensory (visual) input. This throws into question the use of sensory biomarkers to assess symptom load subclinically. We examined visual and auditory excitability in schizotypy to assess their use as a biomarker of symptom load. Participants completed the Schizotypal Personality Questionnaire Brief Revised (SPQBR) and were categorized into high schizotypy (SPQ > 87) and a control group (SPQ-BR = 50-70). Participants completed the PGT, and electroencephalography (EEG) was recorded while they viewed grating patterns that reversed contrast at 4Hz and listened to auditory tones modulated in amplitude at 4Hz, separately. As expected, individuals with high schizotypy reported more illusions from the PGT than controls (Cohen's d = 1.01). They also produced larger visual steady-state responses compared to controls (Cohen's d = 0.3). However, the high schizotypy group exhibited smaller auditory steady-state responses (Cohen's d = 1.12). High schizotypy exhibited visual cortical hyperexcitability, consistent with the higher number of illusions seen in the PGT. Whereas they showed auditory cortical hypo-excitability, which is consistent with the auditory responses seen in schizophrenia. This divergent multisensory profile in schizotypy may be crucial in helping us understand how the underlying pathology changes with symptom progression.

#22: Audiovisual signals shape our perception of materials in virtual reality

Harshitha Koppisetty, Robert Allison, & Laurie Wilcox
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We investigated how visual and auditory properties affect our material perception when these attributes conflict, and whether the outcome depends on our interaction with the object. A VR headset displayed a target object that was struck with a rod and made an associated impact sound. The participant classified the target material using four options: glass, metal, plastic, or wood. All the sounds were presented with each of the visual textures resulting in 16 conditions. To study the effect of agency, in half the trials the participant struck the target using a rendered rod and a VR controller; in the rest they observed an agent striking the target. Participants (N=42) tended to classify the materials by sound over appearance, but relied more on appearance when the sounds were similar. Agency (direct interaction) did not significantly change the classifications. Finally, there were 3 conditions in which participants frequently classified the target as a third option that matched neither appearance nor sound – suggesting a material-based audiovisual illusion. To date we have used a metal rod to strike the target. Would changing the rod affect participant response? Would these illusions be more likely if sound quality was degraded? We will present the results of ongoing experiments that investigate these questions. Modern technology enables realistic (faux) appearances. Here we show that dissonance with the visual appearance may produce non-intuitive intersensory interactions. These results highlight interesting intersensory dependencies in material perception that should be considered in applications from flooring design to creation of virtual environments.

#23: Verticality perception and balance with no vision: a pilot study

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Gravity is an essential force that shapes human brains, anchoring our perception of the world. Gravity perception (graviception) is crucial for balance and postural control. To investigate graviception, researchers evaluate verticality perception, being the vertical parallel to gravity. With this background, vision plays a key role in spatially perceiving body and environment orientation. In this pilot study, we investigated the association between idiosyncratic participants' sway in stance (i.e., variation of their center of mass across time) and their precision in perceiving verticality through the haptic exploration using the Subjective Haptic Verticality task (SHV), with no visual cues available. Eleven healthy participants (mean age±SD y.o. = 29.2±3.1) are involved. Their sway is measured using a commercial balance platform (Wii Balance Board; 3 trials in silence, 60 sec each). For the SHV task, participants are required to adjust the orientation of a 3D-printed plastic bar, aligning it to the vertical using only haptic cues (18 trials). Error and variability of verticality perception are computed. After standardization, we correlate the variability in verticality perception and the sway. Although no significant correlation is found between the two variables, we observe a trend suggesting that greater precision in haptic verticality perception (lower variability) may be related to poorer stability while standing (more sway). Increased sensitivity in perceiving verticality may indicate a higher frequency of postural adjustments, i.e. more sway. Future studies will shed more light on the contribution of vision to balance and postural control, considering the potential clinical implications for the visually impaired population.

#24: Investigating the Validity of the Hue-Heat Effect: A Study on Thermal Sensitivity

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In this study, we aimed to investigate the validity of the hue-heat effect on the body thermal sensitivity. Previous research on thermal comfort has proposed associations between red and warmth, and blue with cold. However, inconsistencies in confirming this effect have arisen, with studies often relying on subjective scales for thermal comfort assessment, introducing potential confounding variables. To overcome these limitations, we conducted a study focusing on the hue-heat effect within the domain of thermal sensitivity, providing a more objective measurement of thermal perception. Participants (n = 26) were required to compare the perceived temperatures inside different climate chambers lighted by either red or blue lights. In the congruent condition, the warmest chamber was lighted by red lights, while the coldest chamber had blue lights. On the contrary, the incongruent condition featured the warmest chamber with blue lights and the coldest chamber with red lights, thereby violating the hue-heat effect. Notably, some participants aligned with our hypothesis, while others exhibited opposing behaviour. The analysis revealed comparable performance in both conditions (the Generalised Linear Mixed Model that best described the data did not include the two conditions as a fixed effect: R2 marginal = 47%, R2 conditional = 51%), challenging the hypothesis that congruence between colour and temperature enhances thermal perception. Additionally, the sensitivity observed in this experiment was lower than identified in our previous study (p-value = 7.87*10-6), suggesting that the colour of the lights might have increased participants' cognitive load, leading to a decline in their performance.

#25: Rapid reconfiguration of cortical networks under visual-vestibular conflicts

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1 Zhejiang University, 2 Sun Yat-Sen University

Multisensory integration is essential for postural control. If brain has difficulty reweighting conflicting sensory inputs and heavily relying on the less reliable inputs, postural stability would decrease especially for the older adults. Recent studies used the connectivity of source-level EEG, providing an insight to explore how brain reweights multisensory inputs for postural control. Our lab presented visual-vestibular congruent (natural visual experience) and incongruent condition (conflicted visual experience) conditions through synchronously controlling a rotating platform and a visual scene in VR headset. Our first study was to explore how the conflicts affect postural stability and cortical networks (i.e., directed connectivity) for young (n=18) and older (n=18) adults. We asked young and older adults to complete the standing task once under incongruent condition. We found older adults induced more pronounced postural instability and more information flow of visual cortex, suggesting older adults have difficulty down-weighting the less reliable visual information. Our second study was to explore whether balance training under either congruent (n=13) or incongruent (n=14) condition improve postural stability and reconfigure cortical networks for young adults. We asked young adults to complete standing tasks five times either under the congruent or incongruent condition. We found balance training under both conditions improved postural stability with different reconfiguration of cortical networks. Balance training under conflicts decreased the information flow of visual cortex, while balance training under congruent condition increased the information flow of parietal lobes. These results suggested that young cortical networks have the ability to flexibly and dynamically reweight multiple sensory inputs.

#26: Rebound nystagmus reflects a velocity-based set-point adaptation in the oculomotor system

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3 ASRC Federal Data Solutions, 4 Johns Hopkins University

Previous studies have shown that holding gaze at an extreme eccentricity generates a drift back to central gaze (Gaze-Evoked Nystagmus or GEN), but also a drift back to the previously held gaze location upon returning to central gaze (Rebound Nystagmus or RN). RN reflects an adaptation mechanism that changes the properties of the gaze-holding system after prolonged eccentric gaze holding. However, it is unknown whether this mechanism reflects a position or velocity set-point adaptation or both. Here we take advantage of the non-linear behavior of the gaze-holding system by testing RN at a range of horizontal eccentricities to determine what set-point is changing. Six subjects were instructed to hold their gaze at 40 deg to the left or right side of the display for 30 seconds and immediately shift their gaze to one of 11 possible locations (±40, ±35, ±30, ±25, ±20, 0 deg) for 15 seconds where RN was measured. Slow-phase velocity (SPV) was calculated as the median of the slow drift part of the nystagmus in the first 5 seconds of RN. We fitted our SPV data with a model developed by Bertolini and colleagues (2013) describing its non-linear dependency with eye position. The model fits showed that adaptation is more likely velocity- rather than position-based. This may indicate that the brain adapts by introducing a velocity signal that cancels the GEN at eccentric positions and that the signal persists after returning to central gaze. Future studies will incorporate other ocular dimensions such as vertical and torsion.

#27: The Effects of Multiple Physical Factors on Creative Thinking, A Field Study

Sally Augustin & Cynthia Milota
Design With Science

Neuroscientists have comprehensively assessed how design can support creative thinking, most often in studies that detail the effects of a single physical factor. Creativity-linked design elements identified include color (surface and light), visual complexity, plants in view, natural light, visible wood grain, aesthetic factors, soundscapes, comfortable environmental control, distractions, ceiling height, opportunities for movement, access to needed tools/task support, nonverbal messages sent by a space, and chance for cognitive restoration, for example (e.g., Batey et al., 2021; Studente, et al., 2016; Weitbrecht, et al.,2015). For the study reported here, multiple factors linked by previous research studies to enhanced creative performance were investigated simultaneously in a real-world setting. Study participants first completed a task that assessed their individual creativity at a particular moment in time (Green et al. 2017). Then the study participants categorized/described the components of the physical environment in which they did that task using the criteria noted above (e.g., surface colors). Findings confirmed many hypothesized consistencies between aspects of the physical environment previously identified as supporting creative thinking and the design of spaces where participants whose creativity test scores were among the highest 25% ("highest scorers") completed the creativity task. Data from the highest scorers indicated that, compared with other participants, they were more likely to have answered the creativity test questions in spaces with, for example: Surface colors that support cognitive work Possible natural light Plants Woodgrain Nature sounds Comfortable environmental control Ceiling heights linked to enhanced creativity And that were perceived to support mental work.

#28: Unconscious processes underlie reach adaptation to a visuomotor distortion that is mirrored relative to hand motion

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1 Queen's University, 2 University of Ottawa

Implicit, unconscious, processes underlie reach adaptation to a visuomotor distortion when visual feedback regarding limb location is rotated relative to hand motion1 . Here we ask if implicit processes also play a role in visuomotor adaptation to small mirror reversal distortions, where visual feedback of the limb position is reversed across an axis2–4 . Two groups of participants reached towards two targets positioned 10° to the left and right of body midline with visual feedback that was either mirror reversed relative to hand motion (MR group) or rotated 20° relative to hand motion (VR group; see Figure 1). The MR group demonstrated adaptation across training trials with the mirror reversed visual feedback. Specifically, angular errors of the hand relative to the target decreased across training trials, such that the cursor landed on the target by the end of training. This MR adaptation was driven in part by implicit processes, as participants continued to reach away from the target in the absence of visual feedback (i.e., in aftereffect trials), when cued to reach their hand to the target. Implicit adaptation observed in the MR group was less than the VR group, who continued to reach almost 20° from the target during aftereffect trials. Our results suggest that implicit processes contribute to reach adaptation to mirror reversed visual feedback, but to a lesser extent than reach adaptation to rotated visual feedback.

#29: Zooming in: Using ultra-high resolution quantitative and diffusion MRI to uncover the underlying microstructural mechanisms of structural plasticity in congenitally blind humans

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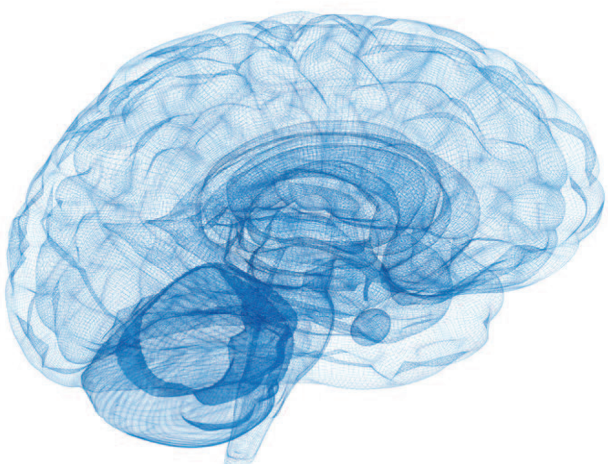
1 Jagiellonian University, 2 Max Planck Institute for Human Cognitive and Brain Sciences, 3 University College London, 4 Leipzig University

The study of blind individuals can provide unique insights into how sensory experience shapes the structural and functional organization of the brain. Studies with enucleated macaques have revealed remarkable alterations in the primary visual cortex (V1), including the emergence of new cytoarchitectonic areas. Studying such microscopic alterations in humans has been challenging due to limitations in conventional imaging methods. Thus, human research has primarily relied on coarse measurements, like cortical thickness and surface area. To fully grasp the potential for structural reorganization in blind humans, we need to go beyond conventional imaging methods that lack information about the underlying myelo- and cytoarchitecture. Our study aims to uncover this potential by investigating differences in the myelo- and cytoarchitecture between congenitally blind and sighted individuals (n = 24 in both groups) in different cortical layers of V1 and its adjacent white matter. To this end, we used ultra-high spatial resolution multiple parameter mapping (MPM) and diffusion-weighted imaging (DWI) to obtain quantifiable parameters, such as the longitudinal relaxation rate (R1), effective transverse relaxation rate (R2*), and proton density (PD), as well as apparent fiber density (neurite density index; NDI) and fiber dispersion (orientation dispersion index; ODI). By applying biophysical modeling, we were able to relate those parameters to the underlying tissue composition, deriving biologically specific measurements. Our data hold significant implications for understanding both typical and atypical brain development. By leveraging state-of-the-art in vivo quantitative measurements, we provide insights into the potential for structural plasticity in blind humans at unprecedented scale.



Poster Session Two

June 18 in DMSC Foyer

#1: 4 Trials is Not Enough: The amount of prior audio-visual but NOT audio-tactile exposure strengthens crossmodal correspondences between nonsense sounds and abstract shapes experienced via touch early in development

Rong Tan, Shibo Cao, & Vivian Ciaramitaro
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In one type of crossmodal correspondence, nonsense words, such as "bouba", are associated with rounded abstract shapes while "kiki" with angular abstract shapes. Such associations are found between auditory and visual stimuli (AV), as well as auditory and tactile stimuli, objects touched but not seen (AT). Visual experience can influence AT associations: AT associations are weak in early-blind adults (Fryer et.al, 2014) and fullysighted 6-8 year-olds with naïve visual experience of abstract shapes (Chow et.al, 2021). Interestingly, repeated testing in early-blind adults (Graven & Desebrock, 2018) and prior AV experience in fully-sighted children (Chow et al, 2021) can enhance AT associations. Here, we examine how the amount of prior visual exposure alters AT association strength. Sixty-one 6-8 year-olds saw 4 or 8 trials of prior AV exposure and were compared to our previous study using 16 AV or AT trials. AV exposure presented a round and spiky visual shape on a screen, side-by-side, and children indicated which shape best matched a nonsense sound. After exposure, children completed 16 AT trials, where they felt two tactile shapes inside a box, hidden from view, and indicated which shape best matched a nonsense sound. We found that 8, but not 4 trials of prior AV exposure enhanced AT association strength. Importantly, neither 4 nor 8 trials of prior AT exposure enhanced AT associations. Our findings suggest that the amount, not just the type of prior exposure is important early in development in finding evidence for sound-shape correspondences between sounds and tactile shapes.

#2: A ceiling effect for the amount of visual information needed to estimate travel distance

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1 York University & 2 Justus-Liebig University Giessen

Knowing about self-motion is a multisensory task. Previous research from our lab (Bansal et al. JOV 2023; 23(9):5075) found that estimated travel distance when visually moving through virtual environments is unaffected by variations in structure, texture, or naturalism. A likely explanation is that there may be a ceiling effect once the minimum amount of visual information needed to make travel distance estimates is reached. Here, we used virtual reality to visually "move" participants (n=20) through a virtual street scene, judging distances by stopping at the location of a previously seen target (Move-To-Target) or adjusting a target to indicate the distance of a previously experienced movement (Adjust-Target). For both tasks, participants were moved through four environments: full street, streetlights only (peripheral visual field), road only (lower visual field only), and blank screen (no optic flow). For Move-To-Target, the full street condition was associated with more accurate gains (perceived travel distance / actual travel distance) compared to the streetlight and road only conditions. The streetlight only condition was also associated with higher gains than the no optic flow and road only conditions. For the Adjust-Target Task, the full street condition was associated with higher gains than the no optic flow condition, but no differences were found between the other environments. Our results likely confirms that there is a ceiling effect that occurs once the amount of visual information needed to accurately perceive travel distance is extractable from the scene.

#3: Age differences in the effect of a virtual full-body illusion on peripersonal space

Dariusz O'leary 1, Yichen Fan 1, Andrea Serino 2, & Shu-Chen Li 1
1 TU Dresden & 2 University of Lausanne

With increasing access to multi-sensory digital technologies, it is important to understand processes and individual differences in the representation of space around the body, known as peripersonal space (PPS), in virtual environments. Although it has been shown that inducing virtual full-body illusions can expand PPS, it is unknown whether such illusions affect PPS around the physical body location only, or if PPS also transfers to the virtual body. Moreover, while the effects of virtual full-body illusions on PPS have been explored in young adults (18 – 30 years), they are yet to be examined in older adults (65+ years). We utilised visuo-tactile stroking in a virtual reality setup to induce a full-body illusion and manipulated illusion strength by administering either synchronous or asynchronous stroking. Following illusion elicitation, the representation of PPS was measured using a visuo-tactile task employing receding visual stimuli and participants' sense of embodiment was assessed through a standardized questionnaire. The results showed that for young adults (N = 27) synchronous stroking led to a transfer of PPS to the virtual body, as well as a stronger experience of avatar embodiment compared to asynchronous stroking. In contrast, in older adults (N = 26) no transfer of PPS to the virtual body was observed, despite synchronicity also impacting their experienced embodiment. These results offer important insights into the adaptation of PPS to virtual environments and reveal that aging affects this adaptation. These findings are not only relevant for multisensory research but will also inform the age-inclusive design of virtual applications.

#4: Audiovisual Temporal Numerosity Training Alters Multisensory Integration and Unisensory Processing

Kimia Kamal, Saul Quintero, & Ladan Shams
University of California, Los Angeles

Our perception of the world is intrinsically multisensory, yet the mechanisms of sensory integration and their malleability remain poorly understood. Building on foundational insights into multisensory processing, where causal inference shapes our sensory experiences, we explore the impact of different types of audiovisual temporal numerosity training, counting flashes or beeps with feedback, on unisensory processing and the tendency to bind sensory information. Participants were randomly assigned to one of four training groups: congruent (matched number and timing of beeps and flashes), incongruent (mismatched number of beeps and flashes, same overall timing), unisensory, or control (no training). Participants were tested in a temporal numerosity task (without feedback) before and after training, which allowed assessment of change in performance in both unisensory and bisensory conditions due to training. Analyses considering both accuracy and reaction time reveal an improvement in visual and auditory processing in all training groups. Interestingly, multisensory benefit (the improvement in accuracy in congruent trials compared to unisensory trials and a measure of audiovisual integration) increased significantly in the congruent training group ($p<0.05$) and decreased in the unisensory group ($p<0.05$), with no changes in the incongruent and control groups. These results emphasize the critical role of temporal synchrony in shaping the tendency to integrate senses. The stable binding tendency following 'incongruent' training suggests that temporal congruence might counteract incongruencies in other dimensions, such as numerosity. This significant impact of temporal synchrony on shaping the binding tendency is consistent with our previous findings (Odegaard, Wonzy, & Shams, 2017).

#5: Auditory Perception is Reflected through Pupillometry Irrespective of Visual Working Memory Load

Phivos Phylactou 1 & Nikos Konstantinou 2
1 University of Western Ontario & 2 Cyprus University of Technology

Vast research has demonstrated that increased visual working memory (VWM) load results in pupil dilation. Additionally, evidence suggests that auditory perception can also be reflected through pupillary responses. However, it currently remains unknown whether pupillometry can be used to study VWM and auditory perception cross-modally, or whether the robust, modality-specific effect of VWM load on pupillary response will hinder that of auditory perception. In a combined VWM and auditory detection task, we investigated this question. Thirty-one participants performed a delayed-match-to-sample VWM task of either low (one colored square) or high (four colored squares) VWM load. Participants responded to an auditory stimulus detection task during the VWM maintenance period. The auditory detection stimulus (1000 Hz pure tone) was presented randomly in half of the trials at a predetermined, individual threshold level. Pupil size was measured during the VWM maintenance period at 1000 Hz, in a dimly lit dark room. A Bayesian repeated-measures ANOVA indicated that the data were best described by a model including both the VWM Load (low vs. high) and the Auditory Perception (present vs. absent) factors (BF = 3.18). Notably, this model superseded the model including an interaction between VWM Load and Auditory Perception (BF = 3.25). Our results indicate that a pupillary response, reflecting a pupil dilation, is reflected for both VWM Load (BF = 2.66) and Auditory Perception (BF = 3.09) independently. This finding demonstrates that pupillometry might be a useful tool for cross-modal or multisensory VWM research.

#6: Cardiac phases modulate the crossmodal freezing effect

Zengliang Chen & Lihan Chen
Peking University

Interoception, typically as a way of self-perception of one's cardiac cycle phases has been revealed to modulate the multisensory integration in simple detection task, with differential effects when the stimuli are locked to either diastole or systole phases. Here we examined whether cardiac phases also impact the multisensory integration in more dynamic, complex scenario. Moreover, we asked whether the different combinations of crossmodal stimuli (visual-tactile, visual-auditory and visual-auditory-tactile) would exhibit different impacts due to the interception and extroception interaction. To achieve above purposes, we employed cossmodal freezing effect, which refers to a compelling perceptual benefit in which an abrupt sound "freezes" a rapidly changing visual display and makes the otherwise undetectable visual object being popping out. We designed a 'diamond' visual target (composed by dots) which was masked in a rapid visual sequence. The distractor stimuli (auditory, tactile or synchronous audiotactile stimuli) were presented 250 ms after the R-peak in the systole condition, and 500 ms after the R-peak in the diastole condition, locked to the presentation of visual target. The preliminary findings suggested that correction rates for detecting the target in systole phase were lower than the ones in diastole phase, typically for the visual-auditory and visual-auditory-tactile conditions. On the other hand, it took longer for the observers to detect the target in systole phase, typically for the pure visual and visual-auditory-tactile conditions. Those findings could be reconciled in a predictive coding framework and indicate a general interference of multisensory integration in systole phase.

#8: Optic flow and active leg movements activate the human middle temporal cortex

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1 Università degli Studi di Roma Tor Vergata, 2 Università degli Studi di Roma "Foro Italico", 3 Università degli Studi del Molise, 4 Alma Mater Studiorum Università di Bologna, 5 Università degli Studi di Roma "La Sapienza", 6 Università degli Studi di Roma "Foro Italico"

The cluster of areas usually referred to as MT+ (areas MTS, FST, MT, V4) is one of the most prominent motion-sensitive regions in the human middle-temporal cortex. Recently, it has been found that MT+ shows some degree of preference for ego-motion-compatible optic flow and is modulated by extraretinal signals. These results suggest a possible motor role of MT+ in visually guiding movements of the upper and lower limbs during walking. Here, we tested this hypothesis using functional fMRI; we aimed to study the sensitivity of MT+ to process motion information from non-visual modalities through a pure motor task. Specifically, in a large sample of subjects, we investigated whether the subdivisions of MT+ are differently modulated by optic flow and arm and leg movements. Moreover, we computed the functional connections between these regions and the rest of the brain. We found that only MST and FST were sensitive to optic flow, as measured by the difference between coherent (radial and rotational) vs. random visual motion. Consistently, we also found that leg movements positively activated MST and FST, while MT and V4t were deactivated by arm movements. In line with these results, we found that FST and MST were highly connected and showed a distinct widespread pattern of functional connection involving somatosensory and motor areas. Overall, these results provide evidence that MT+ hosts two visuomotor areas anteriorly (MST and FST) and two visual areas posteriorly (MT and V4t), consistent with nonhuman primate studies.

#9: Effects of Torsional Eye Position During Head Tilt on Perception of Upright in Virtual Reality

Reem Almagati 1 & Jorge Otero-Millan 1, 2

1 University of California, Berkeley & 2 Johns Hopkins University

As we move about the world, our eyes, head, and body are constantly moving, yet we experience the world to be stable and upright. Perceptual stability in the presence of retinal motion has been investigated in horizontal and vertical dimensions. Retinal motion also exists in the torsional dimension when the eyes rotate about the line of sight. Changes in torsional eye position can occur with head movement and convergence. When the head tilts towards the shoulder, a compensatory mechanism occurs, ocular counter roll (OCR). The amount of OCR is reported to be 10-20% of the head tilt angle (Linwong M, Herman SJ. 1971 & Collewijn H, et al 1985). This incomplete compensation for head tilt will subsequently result in a tilted retinal image. Studies have reported an even smaller OCR with convergence (Ooi, et al 2004). I utilized this interaction to study the effects of torsional eye position during head tilt on perception of upright. Subjects viewed a vertical line in VR presented at nine different angles (-12° to +12° in three degree steps) with the head upright, 20° right ear down and 20° left ear down. The line was viewed at two vergence distances (0.25m and 1.5m). The fixation spot remained binocular while the SVV test line was viewed either monocularly or binocularly. My findings suggest that SVV errors are biased in the direction of head tilt. In conclusion, perception of upright in VR is mainly influenced by the position of the head.

#10: Enhancing Tactile Perception Through Cognitive Training: Cross-Modal Correspondences and Perceptual Learning

Ofek Salama , Adi Snir, & Amir Amedi
Reichman University

Our study investigates the enhancement of tactile perception through cognitive training, examining its impact on tactile-to-visual association tasks and distinguishing between the effects of cross-modal correspondences and perceptual learning. Through a methodical analysis of changes across training sessions, we assess how these tasks influence spatial discrimination and task accuracy, revealing patterns of perceptual adaptation. Our methodology tracked participants' performance across several sessions, identifying how cross-modal correspondences facilitate initial improvements and how continued training fosters perceptual learning, characterized by increased spatial discrimination and refined tactile-visual integration. The results demonstrate a phased learning process, with immediate benefits from cross-modal correspondences and sustained enhancements through perceptual learning, highlighting cognitive training's potential to fine-tune multisensory integration. These insights contribute to our understanding of sensory processing and learning, emphasizing cognitive training's role in enhancing tactile perception and its implications for multisensory research, educational strategies, and rehabilitative practices. The findings not only advance our theoretical knowledge but also suggest practical applications in designing sensory augmentation tools and cognitive training programs.

#11: Exploring Shared versus Separate Timing Mechanisms in Sensorimotor Processes

Abigail Liu, Alejandro Cruz, Kezhen Qi, Marcia Grabowecky, & Satoru Suzuki
Northwestern University

Timing mechanisms in the sensorimotor system coordinate sensory, motor, attentional, and cognitive dynamics. Identifying which processes share a common timing mechanism is informative as those processes will likely interfere with one another when driven to engage in incompatible dynamics. While much research has investigated how time perception is affected by motor and cognitive demands, few have explored how the internal oscillator governing motor timing is affected by concurrent engagement in sensory, attentional, and/or cognitive dynamics. In the current study we examined how an individual's intrinsic motor rhythm was affected by engaging in tasks that required sensory, motor, attentional, and/or cognitive dynamics that were incongruent with the intrinsic rhythm. The rate and regularity of spontaneous finger tapping were tracked while participants performed a series of cognitive and sensory tasks. Participants were instructed to tap at their preferred rate during the tasks. The average tapping rate was relatively unaffected by the concurrent tasks. Interestingly, the tapping rhythm (i.e., the temporal regularity of tapping) became irregular when the tasks required speaking (e.g. scripted speech, spontaneous speech, and verbal rehearsal). Other sensorimotor and cognitive processes, including dynamically orienting attention and deploying attention on demand, making eye movements for visual exploration, silent working memory maintenance, and silent reading, did not interfere with tapping regularity. These results suggest that a shared motor timing mechanism controls the dynamics of both spontaneous finger tapping and speaking, whereas distinct timing mechanisms likely govern the dynamic control of attention, eye movements, and other cognitive functions.

#12: Generalizability of acoustic parameters underlying sound symbolism for auditory pseudowords

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Sound symbolism relates to the crossmodal correspondence in which the sounds of words resemble non-auditory properties, e.g., pseudowords like 'kiki' are associated to pointedness, hardness and excitedness. Recently, we employed a K-nearest neighbor (KNN) machine-learning algorithm to identify the combinations of acoustic parameters that best predicted the ratings for a set of 537 pseudowords, developed to study sound shape associations, on seven different meaning domains. We found that each meaning domain was associated with a unique combination of parameters. However, it is unknown whether these parameter combinations and their cross-domain dissimilarities generalize to different pseudowords. Here, we used a separate set of 638 pseudowords, optimized for sound-size associations, to collect sound-symbolic ratings on nine different domains of meaning, including the seven domains used previously. While the optimal set of parameters varied between the pseudoword sets, there were some notable commonalities. We found that the fast Fourier transform was a consistent contributor across the pseudoword sets and meaning domains. Compared to the previous set, the harmonics-tonoise ratio and speech envelope appeared to be more predictive of sound-symbolic ratings for the current set. Interestingly, for both sets, the patterns of cross-domain cosine dissimilarity between the vectors representing the regression weights for each domain appeared to be organized based on relationships between the relevant sensory modalities. Taken together, our results suggest that the combinations of acoustic parameters underpinning sound symbolism vary by domain in a manner reflecting the corresponding sensory modalities.

#13: Immediate phonetic convergence in task-irrelevant vocal pitch features

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1 Ritsumeikan University & 2 Japan Society for the Promotion of Science

Our vocalizations spontaneously converge with others' acoustic features, a phenomenon known as phonetic convergence. Previous investigations have utilized shadowing tasks, wherein participants repeat heard words or sentences, demonstrating convergence to the acoustic features of the stimuli to be repeated. However, it remains unclear whether phonetic convergence extends to the acoustic features of task-irrelevant speech-sound stimuli in non-repeating tasks. In our experiment, participants were instructed to vocalize a predetermined sound, either /i/ or /e/, as quickly as possible based on a visual cue indicating the respective sound. Subsequently, a task-irrelevant high- or low-pitched speech stimulus was presented immediately after the cue. Results revealed that participants' vocalizations shifted to higher or lower pitches in response to the pitch of the task-irrelevant stimuli (see Figure). Furthermore, phonetic convergence was observed in the task-irrelevant acoustic feature within the short time scale of a single speech perception-production loop (compared to the exposure task). These findings suggest that phonetic convergence occurs immediately through the integration of auditory representations from preceding speech perception into the speech production planning process via the speech perception-production link.

#14: Individual Differences in Multisensory Illusory Perception

Maggie Baird, Carmel Levitan, Stephanie Nelli, & Aleksandra Sherman
Occidental College

The sound-induced flash illusion (SIFI) and the McGurk effect are two widely used paradigms for demonstrating powerful multisensory interactions. However, there are substantial individual differences in the extent to which people report experiencing these illusory percepts. We conducted an experiment (N=87) in which we used behavioral and EEG measures to quantify not only variability between participants but also across sessions. Additionally, we investigated whether susceptibility to these two illusions is correlated. We found robust individual variability across both illusions such that some participants always, never, or sometimes experienced each of the illusions. Interestingly, susceptibility to each illusion was stable over time; participants remained either "seers", "non-seers", or "sometimes-seers". It is of note however that there was no relationship between susceptibility to the two illusions. These individual differences in propensity to experience the illusions was reflected in distinct neural signals as measured from central and occipital sites. Trial by trial EEG signals were predictive of whether participants would experience an illusory percept, highlighting the important impact that transient fluctuations in brain state can have on our perceptual experience. This study supports and extends the growing literature surrounding individual variability in perception of multisensory illusions.

#15: Involvement of the primary visual cortex during auditory perception of space

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1 Istituto Italiano di Tecnologia, 2 Università degli studi di Genova, & 3 IRCCS Fondazione Stella Maris

Despite clear evidence of multisensory processes in low-level sensory cortices, the role and specificity of primary visual cortex in audio-visual localization is still unclear. Here we investigated by ultra-high field Magnetic Resonance Imaging (fMRI) the recruitment of visual areas during two different pure acoustic spatial tasks: a localization of sounds in presence or absence of reference sounds. The 10 participants were asked to either localize a sound (± 25 degrees from midline, spatial localization task) or estimate its relative spatial position with respect to the position of two landmarks (± 90 degrees from midline, spatial bisection task) presented 5-8 seconds before the sound. A single subject GLM analysis for the sound contrasted between the two tasks (bisection greater than localization) was entered as dependent variable in a whole brain one-sample t test ($pFWE < 0.05$). Activation in visual areas was modulated by the type of auditory spatial representation elicited by the task. Specifically, we observed higher activation in the bilateral primary visual cortex that represents the peripheral part of the visual field ($pFWE<0.001$) and not in auditory cortices. However, both tasks evoked similar activations in the bilateral auditory cortex ($pFWE<0.001$). These results provide support on the crucial role of visual cortices in the processing of complex spatial information regardless of the sensory modality involved.

#16: Multisensory activity in the auditory cortex of behaving macaques

Huaizhen Cai & Yale Cohen
University of Pennsylvania

Because we live in a multisensory environment, it is reasonable to speculate that our brain has evolved to preferentially take advantage of multisensory information. However, despite a large literature examining multisensory processing, we still do not have a full understanding of how cortical activity (e.g., in the primary auditory cortex [A1]) contributes to multisensory perception. Here, we recorded A1 neural activity in nonhuman primates while they performed an ethologically relevant multisensory detection task that utilized monkey vocalizations and a video of a vocalizing monkey. We manipulated task difficulty by varying the signal-to-noise ratio (SNR) between an auditory target stimulus (i.e., a monkey "coo" vocalization) and a background noisy "chorus" of monkey vocalizations. We found that a temporally and contextually congruent video of a vocalizing monkey improved the monkeys' ability to detect the target vocalization. Our analyses of A1 activity indicated that 1) it was modulated more by visual stimuli in lower SNR conditions than in higher SNR conditions; 2) visual stimuli improved the capacity of linear classifiers to decode target responses from noise responses; and 3) their population neural trajectories encoded the target's SNR. Overall, we found that visual stimuli modulated A1 activity and improved the encoding of auditory stimuli by populations of A1 neurons, which might facilitate auditory perception.

#17: Navigating the Near: VR investigations of peripersonal space in autism

Hari Srinavasan & Mark Wallace
Vanderbilt University

Our research investigates the dynamic interplay between sensory sensitivity and peri personal space (PPS) in autistic and non-autistic individuals using a virtual reality (VR) bubble-pop task integrated with EEG analysis. Our study aims to explore how sensory hypersensitivity influences the boundaries of PPS and the associated physiological response, providing insights into the bidirectional relationship between sensory processing and spatial awareness. Participants, comprising 20 autistic and 20 non-autistic controls, will engage in a VR task designed to simulate PPS intrusions. The task is personalized through arm-length measurements to accurately assess each participant's PPS. Independent variables include bubble speed and distance, treated as continuous variables to derive reaction time (RT) curves. Dependent variables encompass RT gradients, attempt distance, localization errors, hits versus misses, and the physiological measure of heart rate, offering a comprehensive understanding of sensory-motor integration and autonomic responses. Additionally, our study incorporates a non-VR control task to benchmark motor abilities, addressing variations in sensory-motor integration accuracy. EEG data, focused on regions of interest in the brain implicated in PPS, will elucidate the neurophysiological underpinnings of PPS dynamics in autism. Our research aims to reveal how heightened sensory sensitivities modulate PPS boundaries and autonomic activity. By integrating VR, EEG, and control tasks, the study aims to contribute insights into the complex sensory and motor interactions characterizing autism, with potential implications for developing personalized therapeutic strategies.

#18: Stimulus statistics contributing to the integration of motion cues in humans

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The ability to effectively integrate cues from multiple sensory streams and combine them into a unified percept of our dynamic world is vital to coherent perception. Although multisensory motion processing has been explored, it has not been done when concurrent auditory and visual stimuli are both attended (Meyer & Wuerger, 2001; Kayser et al., 2017). We argue that such an approach is a more ecologically valid way to study how we perceive motion in our world. The present study investigates the discrimination of motion direction, using a 2-AFC task with stimuli generated via random dot kinematograms and changes in sound levels across speakers. Using Maximum Likelihood Estimation and race modeling, our results suggest that humans integrate motion cues in a statistically optimal fashion. Modulating the motion strength in the stimuli (i.e., coherence), we also determined the amount of multisensory gain across coherences, showing evidence for the presence of inverse effectiveness. One major finding of the study was substantial variability in performance across individuals for this task. Despite this variability, we were still able to elucidate the key stimulus factors that contribute most to the percept of motion direction (e.g. prior trial direction, stimulus duration, and velocity). In ongoing work we aim to use the variability in individual unisensory performance as a predictor for the degree of multisensory improvement for accuracy and reaction time. These findings lay the groundwork for future neurophysiological studies aimed at better understanding the neural correlates of multisensory motion processing in various contexts (e.g. attention).

#19: V6 Activation in Cortical Visuo-Vestibular Integration of Forward Self-Motion Signals : Insights from combining GVS and fMRI

Sarah Marchand, Marine Balcou, Philippine Picher, Maxime Rosito, Damien Mateo, Nathalie Vayssiere, Jean-Baptiste Durand, & Alexandra Severac Cauquil
Université Toulouse III - Paul Sabatier

The integration of visual and vestibular inputs is crucial for self-motion. Information from these sensory systems merges early in the central nervous system and some cortical areas (V6 and VIP) seem to respond specifically to vestibular anteroposterior information. We now aim to understand further the involvement of these and other areas in self-motion processing when vestibular and visual information are combined with variable congruence and direction parameters. Fifteen subjects underwent an MRI session while receiving visual (optic flow patterns) and galvanic vestibular (GVS) stimuli mimicking six conditions: (1) visual forward, (2) visual backward, visual forward and (3) congruent or (4) incongruent vestibular information, visual backward and (5) congruent or (6) incongruent vestibular information. Adding vestibular stimulation to the visual one reveals several bilateral cortical areas processing vestibular information, located predominantly in the insula. Among these areas and those previously defined in our princeps study, we show that V6 is the only area significantly more activated in the forward (versus backward) and congruent (versus incongruent) conditions. By showing that V6 is more active when visuo-vestibular signals are more ecological (i.e. congruent and specifying forward self-motion), our results support the view that this area plays a crucial role in the visuo-vestibular integration during natural locomotion.

#20: When to escape: differences between peripersonal space and defensive peripersonal space around lower limbs.

Xu Aolong & Durk Talsma
Ghent University

In our daily interactions, we instinctively rely on quick footwork to navigate through various situations. For instance, if a car comes speeding towards us, we instinctively assess the situation and swiftly move out of harm's way. Prior to responding, we consistently evaluate the perceptual attributes of objects through visual and auditory modalities. Little is known, however, about the interplay between multiple senses and our lower limbs. This study aims to investigate how participants perceive and evaluate distances between external (multisensory) stimuli and their lower limbs. To do so, the study employs both neutral and threatening stimuli. Furthermore, the study examines the influence of motion-related factors and the plasticity of participants' Peripersonal Space (PPS) under both dynamic and fixed distance conditions. In the dynamic task, stimuli are initially presented far away and gradually move towards the participants' feet, whereas in the static task, they are presented at a fixed distance. In both tasks participants are instructed to press a button to indicate which distance they consider to be safe. In audio-visual tasks, participants have to respond as quickly as possible whenever they hear a sound that is presented simultaneously with the visual stimulus. Consequently, we expect that negative stimuli will enlarge the PPS around feet compared to neutral stimuli. Besides, we expect to observe the fastest reaction time in the negative and near stimuli conditions, while we expect the slowest reaction time to occur in the neutral and far conditions. This approach is crucial for unveiling the inner workings of human defensive mechanisms in our daily lives, highlighting its pivotal role in comprehending how individuals manage and react to potential dangers.

#21: A generalized sensorimotor number system: evidence from individual differences

Giovanni Anobile [1], David Burr [1], Irene Petrizzo [2], & Guido Cicchini [3]
1 University of Florence, 2 University of Trento , 3 Consiglio Nazionale delle Ricerche

With an inter-individual differences approach we recently described sensorimotor channels translating symbolic numbers into sequences of actions. Here we used this technique to test whether these mechanisms also respond to purely sensory numerical information across space and time (visual arrays and sequences). We measured the precision (Weber Fractions, Wf) in a motor reproduction of symbolic numbers (tap as many times as a target digit) but also that in estimating dots arrays (how many?) and flash sequences (stop the sequence when it matches a target digit). Wfs were then correlated between participants, across numerical targets (N8-32). Considering the individual tasks, we found high positive correlations for neighbouring numbers, decreasing with numerical distance, implying tuning selectivity for both sensorimotor and sensory numerical formats. We then correlated Wfs in one task with that in another task. Results indicate the existence of generalised channels dealing both with digit-to-action transformation and purely sensory encoding of flashes or dots. The performance for numerically similar target numbers were indeed more correlated compared to numerically different targets. Interestingly, this was not the case when comparing the performance obtained for estimation of the number of dots in space with that for estimating the number of visual events in time. Overall, the results indicate the existence of generalized sensorimotor number system integrating information across senses and formats. Moreover, while in line with previous evidence for independent mechanisms encoding numerosity of visual arrays and temporal sequences, the current results indicate that these mechanisms are both linked to the sensorimotor number system.

#22: Assessment of Fluid Cognition in Deaf Young Adults Using the NIH Toolbox

Matthew Dye, Emmanuel Garcia, & Geo Kartheiser
Rochester Institute of Technology

As part of a larger project on the impact of cochlear implantation and sign language acquisition on cognition, we collected behavioral and psychophysiological data from over 200 deaf adults aged 18-30 years. Here we present the initial findings from 155 participants who completed the NIH Toolbox Fluid Cognition battery. This subsample was highly diverse in terms of racial and ethnic background, age of cochlear implantation, age of exposure to ASL, and language proficiency in ASL and/or spoken English. Whilst the NIH Toolbox administration manual indicates that deaf individuals were included in norming data, this sample provides the first opportunity to determine how valid the supposedly domain-general test battery is for individuals who are deaf. Age corrected test scores for the composite fluid cognition measure and the five subtests used to derive that composite are shown in Figure 1. Deaf participants scored at around age norms for the composite, dimensional change card sort, pattern completion and picture sequencing measures. However, performance on the flanker and list sort measures was below age-expected norms. Confirmatory factor analysis revealed unacceptable model fits for an unconstrained single factor model, compared to excellent model fits for a model that linked covariances of the measures where participants performed poorly or for a model with two latent factors that separates out flanker and list sort scores. Reasons for the results will be discussed, including considerations of language processing demands and crossmodal plasticity in individuals born profoundly deaf. Implications for cognitive test development will be considered.

#23: BCI Toolbox: An Open-Source Python Package for the Bayesian Causal Inference Model

Haocheng Zhu 1, Ulrik Beierholm 2, & Ladan Shams 3
1 Soochow University, 2 Durham University, 3 UCLA

The development of methods and tools are important for all branches science, including psychology, neuroscience and more specifically the study of multi-sensory perception. This includes the development of tools to make influential theoretical models more applicable to experimental and practical research. Psychological and neuroscientific research over the past two decades has shown that the Bayesian causal inference (BCI) is an important theory that can account for a wide range of perceptual and sensorimotor processes in humans. We introduce the BCI Toolbox, a statistical and analytical tool in Python, enabling researchers to conveniently perform quantitative modeling and analysis of behavioral data. The toolbox has a graphical user interface and is able to display simulations of output from the BCI model. It is able to work on both stimuli in continuous space (e.g. Ventriloquist illusion) and discrete space (e.g. Sound induced flash illusion, SIFI), and can utilize three common decision making strategies. Furthermore, the toolbox is able to perform model fitting given a user provided dataset, using either Variational Bayesian Monte Carlo (VBMC) or Powell algorithm. We describe the algorithm of the BCI model and test its stability and reliability via parameter recovery. The presented BCI toolbox offers a robust platform for BCI model implementation as well as a hands-on tool for learning and understanding the model, facilitating its widespread use and enabling researchers to delve into the data to uncover underlying cognitive mechanisms. Further development based on feedback from the community will make this an indispensable tool in the future.

#24: Evaluation of ML-Assisted Music Synthesis as an Approach to Spectral Complexity Reduction to Improve Music Perception for Individuals with Hearing Loss

Xander Brewer
NYU

While hearing assistive technologies can restore clarity to speech for individuals with hearing loss, music is often collateral damage in this transaction, as reported by many users of hearing aids. Some studies (e.g. Nagathil et al., 2015) have shown that reducing the spectral complexity and emphasizing the musical information of audio is largely preferred by hearing impaired individuals. This research aims to explore and evaluate using music transcription and synthesis for processing musical audio to improve the perceptibility and preference for hearing impaired listeners.

#25: Integrating proprioceptive and tactile signals in tool use: impoverished touch causes systematic misperception of object size

Simon Watt & Victor Tindle
Bangor University

For devices such as tools and prosthetic hands to be controlled with refinement approaching normal hand function they must provide useful haptic feedback (that can be integrated with vision). We investigated one aspect of this: haptic size perception. Although hand opening appears to directly signal object size, it can also vary due to compliance of objects and of the digit tips. Accurate haptic size estimation therefore requires integration of proprioceptive signals to hand opening with tactile signals about object material properties, contact, and grip force (Berryman et al., 2006). We investigated whether haptic size estimates are accurate when using simple tongs-like tools, which alter these tactile signals, but leave proprioception intact. Blindfolded subjects felt stimulus objects and reported which of a set of blocks (1 mm increments), felt with the other hand, matched their size percept. We varied object size (34, 41, 48 mm), object compliance (hard, medium, soft), and tool-tip compliance. A training period with vision provided an opportunity to learn how signals acquired via tools related to object properties. Subjects' size estimates scaled with object size in all conditions, indicating they could judge size reliably with tools. There were systematic biases, however. Size estimates were slightly smaller when feeling objects with softer tool tips, and substantially smaller when feeling softer vs. harder objects. These results suggest object compliance, especially, is not taken into account in haptic size estimates acquired with tools. This poses challenges for device development, suggesting ways are needed to enhance or substitute relevant tactile signals.

#26: Real phenomena in unreal places: Exploring human perception in digital realities

Jonas De Bruyne 1, 2, 3, Klaas Bombeke 1, 3 & Durk Talsma 1
1 Ghent University, 2 Research Foundation - Flanders , 3 imec-mict-UGent

Immersive technologies have surged to the forefront of technological innovation, as underscored by significant investments from industry giants like Meta and Apple into their respective mixed reality devices. As these technologies continue to advance, this trend suggests that virtual reality (VR) and mixed reality (MR) will increasingly permeate various aspects of our lives, reshaping how we interact with the digital world. Given this trajectory, exploring multisensory processing within these emerging realities becomes crucial, especially because of the ever-blurring boundaries between the real and the virtual. As these novel realities challenge our perceptual systems in unique ways, expanding the scope of the research field to encompass multisensory processing in immersive virtual environments is imperative. Such knowledge will not only provide valuable insights for optimizing immersive experiences but also drive technological advancements. For instance, leveraging phenomena like the ventriloquism effect—wherein a sound is mislocalized towards the position of a co-occurring, albeit misaligned, visual stimulus— holds promise in reducing computational demands while maintaining high levels of immersion and experience quality. Therefore, this presentation will delve into the evolving landscape of immersive technologies, explore their influence on traditional perception and highlight the necessity for broadening the research scope.

#27: The Effect of Plantar Cutaneous Afferents on Visual Field Dependence in Older adults

Pierre-Olivier Morin 1, Christine Assaiante, Angelo Arleo 2, & Catherine Agathos
1 The Vision Institute, 2 Société Essilor

Postural control and spatial orientation rely on multisensory integration and reweighting. Aging entails sensorimotor declines, and it is marked by an upweighting of visual cues (visual dependence), leading to alterations in how older adults perceive and interact with their environment, which can increase fall risk. We investigated how changes in the integration of plantar cutaneous afferents affect spatial orientation in aging. 33 young adults (29.24.9) and 42 older adults (75.95) were tested on the rod and frame test (RFT) to assess their visual dependence (error with respect with gravity in degrees). Tests were repeated while sitting and standing barefoot. Participants' plantar quotient, which indicates the contribution of plantar cutaneous afferents to postural control, was determined based on postural stability measures while standing on a firm versus compliant surface. There was a general trend of decreased visual dependence when standing compared to sitting, with large variability, especially among older adults (young adults: range -1.58° to 2.15°, standard deviation 0.68°; older adults: range -3.86° to 2.84°, standard deviation 1.51°, see Figure 1a). This variability in older adults was associated with their plantar quotient: the more individuals were able to exploit plantar cutaneous cues, the more their visual dependence decreased while standing $r = -0.314$, $p < 0.01$. This study suggests that plantar sensitivity modulates sensory reweighting for spatial orientation. Further research on the mechanisms underlying these effects could provide insights that may be used in clinical practice for fall risk prevention to promote sensorimotor adaptation in older adults.

#28: The Rubber Foot Illusion is Not Constrained by Anatomical Plausibility

Max Teaford, Shyla Khan, Tanner Greene, Marlene Mejia, Madison Murray, Pauline Deyo, Landon Gaines, Jacqueline Lawshe, & Jackson Shaheen
The University of Tennessee at Chattanooga

The Rubber Foot Illusion (RFI) is an illusion in which one experiences a model foot as their own through synchronous visuo-tactile stimulation. Previous research suggests that the conditions in which the RFI can be elicited under are similar to those of the Rubber Hand Illusion (RHI). However, it was unclear whether the RFI can occur with the model foot in an anatomically implausible position (i.e., rotated 90 degrees relative to the participant's foot). Based upon past research on the RHI we expected that if the model foot was in an anatomically plausible (i.e., toes facing the same direction as the participant's) position, participants would experience the RFI; whereas, if the model foot was in an anatomically implausible position, they would not. To test this hypothesis, 40 individuals (34 female) experienced 6 different types of visuo-tactile stimulation. Before each type of stimulation, participants made judgements about the position of the midline of their foot. After 90 seconds of each type of stimulation, participants made another judgement about the midline of their foot and answered questions about their experience. Contrary to the hypothesis, it was found that individuals reported higher levels of body ownership when the visuo-tactile stimulation was synchronous than when asynchronous or visual only (all p values $< .01$), regardless of the position that the model foot was in. This suggests that proprioceptive information may be weighted less heavily in the RFI than it is in the RHI, likely due to the distance it must transverse to reach the brain.

#29: Vestibular Damage due to Noise Exposure Leads to Significant Sensory Adaptations During Quiet Stance

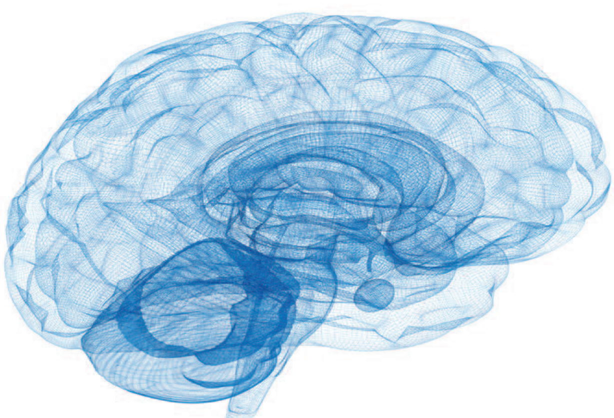
Natela Shanidze, Catherine P Agathos, & Anca Velisar
The Smith-Kettlewell Eye Research Institute

Noise exposure (NE), while long implicated in loss of hearing, has only recently gained recognition as a cause of vestibular loss. Depending on the type of NE, damage may be acute or cumulative, uni- or bilateral. In the case of incomplete, bilateral damage, sensory reweighting adaptations may effectively conceal noise-induced vestibular damage. In this study we examined the effect of lifetime NE on postural sway. We assessed lifetime NE in 8 participants using the Noise Exposure Structured Interview, which is designed to quantify lifetime NE due to recreational, occupational, and firearm noise. Postural stability was assessed standing on a force plate, under four conditions: eyes open, firm surface; eyes closed, firm surface; eyes open, foam; and eyes closed, foam. While participants did not show differences in sway area or sway velocity while standing with their eyes open regardless of NE level, perturbing visual and proprioceptive feedback (eyes closed, foam) led to significant correlations between level of NE and: sway velocity ($R2 = 0.75$, $p = 0.005$) and total sway area ($R2 = 0.65$, $p = 0.015$). Additionally, removal of visual feedback alone (eyes close, firm surface) leads to a significant correlation between level of NE and sway area ($\rho = 0.90$, $p = 0.005$). Preliminary analyses suggest this latter relationship can be affected by fitness (timed-up-and-go time) and age. Taken with our prior findings on gravity perception tasks, these data strongly suggest that NE leads to significant vestibular damage that may go undiagnosed due to sensory substitution mechanisms.

#30: Preliminary evidence for altered audiovisual spatial bias in autism

Sarah Vassall & Mark Wallace
Vanderbilt University

Natural environments are richly multisensory, and integration of information across the senses creates our perceptual gestalt. However, in autism, differences in multisensory integration (MSI) ability are known to correlate with increased presentation of some of the core and associated features. While differences in audiovisual temporal integration have been well characterized in autism, we are aware of only a single study that has begun to examine audiovisual spatial integration in this population. We recruited autistic children aged 7-17 years and age-matched controls to localize white noise bursts presented along the horizontal azimuth, either alone or with spatially congruent or incongruent visual flashes while EEG was collected. Incongruent visual cues typically bias perceived auditory location toward the visual stimulus, with the degree of bias diminishing with spatial disparity. We found that performance in the non-autistic controls' followed these expectations. In contrast, autistic individuals exhibited a smaller but consistent bias across all spatial disparities, suggesting that they have a wider, flattened distribution for audiovisual spatial integration, and thus weaker spatial integration. In the 150-300 ms post-stimulus window, controls' parietal activations for congruent trials were sub-additive compared to the sum of auditory and visual activations; the reverse was true in the autistic group. Hence, the neural generators leading to these different patterns of audiovisual spatial integration are strikingly different. Combined, our preliminary evidence supports our a priori hypothesis of weaker audiovisual spatial integration in autism.



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