International Multisensory Research Forum 2017

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Abstract Supplement

Table of Contents

Workshop Abstracts

Multisensory Integration and the Reproducibility Crisis

Organizer: Sarah Baum, Ph.D.

Recently, a wave of concern has arisen over the lack of reproducibility in many areas of psychology and biomedical sciences. Over 10 years ago, Ioannidis suggested that "most published research findings are false" (Ioannidis, J.P. (2005) Why most published research findings are false. PLoS Med, 2(8), e124). More recently, the Open Science Collaboration highlighted failures to replicate dozens of psychology experiences. The ensuing community-wide debates and discussions provide a perfect background to reassess our own methodology and ask how we can increase the reproducibility of our work. In this workshop, we adopt a tutorial approach to provide attendees with three potential solutions to the reproducibility problem in the domain of multisensory integration, using audiovisual speech perception (especially the McGurk effect) as our test case.

The first solution is converging evidence from multiple methodologies. In the first hour, Michael Beauchamp will present an overview of how using a variety of different methods, including evidence from fMRI, ECog, TMS and behavior can provide converging evidence on the neural substrates of multisensory phenomena that address potential concerns that would arise over individual modalities in isolation. For instance, BOLD fMRI is the most common technique for measuring brain function but has a temporal resolution that is a thousand times slower than individual neural events.

The second solution is increasing statistical power. One of the defining features of studies that have failed to replicate is a lack of statistical power. In hour two, John Magnotti will overview how this impacts studies of multisensory integration and how to use on-line data collection service (amazon Mechanical Turk) to directly address this problem. A tutorial approach will be used to show attendees a step-by-step approach to collecting data on-line. A key element of this is to increase the amount of data sharing and code sharing. Data sharing allows other researchers to reanalyze the data, while code sharing allows researchers to examine the code for bugs. The authors have created a web site in which all analysis code and date from recent publications is shared http://www.openwetware.org/wiki/Beauchamp:DataSharing.

The third solution is to quantitatively test theories. With the vast amount of data now collected, it is a foregone conclusion that some variable in the dataset will correlate with

some variable. With no quantitative a priori theory and flexibility in data reporting and analysis, these correlations are almost impossible to interpret. We demonstrate quantitative model comparison in three steps: construction, fitting, comparison, The goal of quantitative model comparison is not to make binary decisions (X condition has an effect or not), but rather to compare the adequacy of models to explain the data. The quantitative nature of the models make them easier to falsify, without compromising our ability to learn from data (and modify the models).

Bridging the Gap: From Spikes to Behavior

Organizer: Antonia Thelen, Ph.D.

Research on multisensory processing aims to understanding how the brain builds a meaningful and readily usable representation of reality by combining information from disparate sources. In doing so, it faces, almost by definition, the challenge of dealing with many distinctive features of each particular sensory modality, both in terms of stimulus properties and neural circuitry/nodes involved. Further, although multisensory integration occurs within higher-level association areas, there has been evidence for multisensory interactions occurring already within lower, (peri-)primary sensory areas.

Up to date, relatively little is known regarding the neural mechanisms that permit communication along the cortical hierarchy (although a few hypotheses have been advanced, e.g. multiplexing via distinct oscillatory frequencies, communication through coherence within and across frequency bands, evident in data stemming from both intra- and extra-cranial levels) giving rise to efficient subcortical and cortical interactions underpinning unisensory representations. These interactions are even less well understood when considering how information from distinct sensory systems is combined together at different neural stages to give rise to a multisensory representation. This is partly due to the difficulty in isolating the specific contribution of the single modalities and inputs from different cortical areas into neuronal receptive fields.

Numerical and analytical techniques in computational neuroscience can be a powerful aid to disentangle empirically derived data, by formulating adequate hypotheses and testable predictions. Reductionist models, for example, have been partially successful in describing casual neural interactions in areas such as the prefrontal cortex, and in predicting behavioral outcomes during simple tasks. However, models are often plagued

with either lack of biological realism, which renders their direct translation into experimental settings difficult or even feasible or with excessive attention to the minutiae of the particular task they have regionally been inspired by, thus resulting in being hardly generalizable. Meanwhile, empirical neuroscientists propose explanatory models, with very limited predictive power, in line with copious volumes of acquired experimental data (dealing with different SNRs). Such models are usually complex and are generalizable to other experimental settings in a limited fashion (i.e. can be heavily affected by unexplained neural "noise").

Our aim for this workshop is to bring together theorists and neurophysiologists to emphasize the efficacy of multi-scale and interdisciplinary approaches to the understanding of multisensory processes, with a particular emphasis on the theme of collaboration between experiment and theory.

Symposia Abstracts

Crossmodal Plasticity in the Auditory Cortex Induced by Sensory Deprivation during Development and Adulthood

Chair: Brian Allman, Ph.D.

Following damage to a major sense, crossmodal plasticity occurs whereby there is an increased responsiveness in the deprived cortex to the remaining, intact senses. As will be discussed by the invited speakers, a variety of electrophysiological, psychophysical, and functional imaging techniques have been used in hearing-impaired humans and other animals to reveal that the nature and extent of cortical crossmodal plasticity depends on the severity of the hearing loss (e.g., profound deafness versus mild hearing impairment) as well as the age at which the deprivation commenced (e.g., early life versus adulthood). During the proposed symposium, the collective work of the four invited speakers will describe an exciting series of mutually- supportive studies which demonstrate that: 1) mild hearing loss in adulthood is sufficient to induce changes in how the auditory cortex processes both acoustic and non-acoustic stimuli (Dr. Sharma, high-density EEG in humans; Dr. Allman, in vivo single-unit recordings in rats); 2) crossmodal plasticity is not restricted to the auditory cortex, as visual and multisensory cortices show differential changes in sensory processing following hearing impairment (Dr. Allman); 3) synaptic plasticity occurs at specific layers of the auditory cortex following adult-onset visual deprivation (Dr. Lee, in vitro electrophysiology in mouse brain slices), and 4) crossmodal plasticity in the auditory cortex underlies the enhanced visual processing observed in the deaf (Dr. Lomber, complex behavioral testing in deaf cats). It is anticipated that the breadth of techniques discussed, as well as the implications of the findings to residual auditory, visual and multisensory processing will appeal to a large number of members of the IMRF community.

Speakers:

- Anu Sharma, Ph.D. - Crossmodal Plasticity in Developmental and Age-Related Hearing Loss
- Brian Allman, Ph.D. - Crossmodal Plasticity in Auditory, Visual and Multisensory Cortical Areas Following Noise-Induced Hearing Loss
- Hey-Kyoung Lee, Ph.D. - Crossmodal Plasticity in Auditory Cortex Circuit
- Stephen Lomber, Ph.D. - A Causal Link Between Crossmodal Reorganization and Behavior

Symposia Abstracts

The Neurotherapeutic potential of physically driven creature animation in VR

Chair: Andrea Serino, Ph.D.

Basic research in multisensory integration in the last 20 years has strongly improved our insight about the brain mechanisms of multisensory perception and experience. We are now ready to apply this basic knowledge to explore novel ways of administering and controlling multisensory inputs to manipulate experience with the aim of exploring new experimental paradigms or providing novel training for brain disorders. Virtual reality (VR), in particular, also thanks to major technological advancements in the field in the last few years, is a powerful tool allowing controlled exposure to multisensory events. In this MindMaze symposium, we will present most research VR-based approaches to neuroscience and neurorehabilitation. The symposium is structured into four talks, progressively guiding the audience from basic research to translational application.

Speakers:

- Andreas Serino - Multisensory integration of bodily signals within the peripersonal space underling self experience
- Michela Bassolino and Olaf Blanke - Artificial neural signals to induce embodiment: examples of cortical and peripheral stimulation
- Catherine Mercier - Alterations in sensorimotor integration in acute and chronic pain
- Ohmar Ahmad - The Neurotherapeutic potential of VR and animation

Symposia Abstracts

Multisensory Processes: A Balancing Act Across the Lifespan

Chair: David J. Lewkowicz , Ph.D.

Multisensory processes are fundamental in scaffolding perception, cognition, learning and behavior. How and when stimuli from different sensory modalities are integrated rather than treated as separate entities is poorly understood. We review how the relative reliance on stimulus characteristics versus learned associations dynamically shapes multisensory processes. We illustrate the dynamism in multisensory function across two timescales: one long-term that operates across the lifespan and one short-term that operates during the learning of new multisensory relations. In addition, we highlight the importance of task contingencies. We conclude that these highly dynamic multisensory processes, based on the relative weighting of stimulus characteristics and learned associations, provide both stability and flexibility to brain functions over a wide range of temporal scales.

Speakers:

- David J. Lewkowicz, Ph.D. - Development of Multisensory Processing in Infancy & Early Childhood
- Mark T. Wallace, Ph.D. - Development and Plasticity of Multisensory Temporal Function
- Micah M. Murray, Ph.D. - Interdependency of Low-Level Multisensory Processes and Memory Functions Across the Lifespan
- Amir Amedi, Ph.D. - The Brain as a Flexible Sensory-Independent Task Machine: Visual and Multisensory Navigation in the Human Brain and its Dependence on Visual Experience

Symposia Abstracts

Plasticity mechanisms of multisensory integration: neurophysiological data, neurocomputational modeling and clinical perspectives

Chairs: Mauro Ursino, Ph.D., Elisa Magosso, Ph.D., and Cristino Cuppini, Ph.D.

The capacity of the brain to integrate information from different senses into a coherent percept is a fundamental topic in cognitive neuroscience. Experimental evidence shows that multisensory integration is not fully established at birth, but develops with age, can plastically change with experience, and may be partly compromised in neuropsychiatric conditions (such as autism spectrum disorders, ASD). The present interdisciplinary symposium represents an extension of a symposium on the same topic presented at CNS last year. However, although we cover partially similar topics, we extend the debate to other issues and present a rather different perspective, laying emphasis on how multisensory integration can be plastic, and which learning mechanisms at the neural level can explain such plasticity to realize a near-optimal estimate. To this aim, we will present plasticity models of multisensory deprivation in the superior colliculus neurons, experience- dependent changes in the multisensory representation of space and alteration in audio-visual integration in typical and atypical (ASD) development. All these aspects underline a pivotal role played by experience and plasticity in our multisensory integration capacity. Finally, we will discuss how neurocomputational models, based on biologically plausible neural networks, can provide a possible coherent framework to explain these developmental changes, based on reliable synaptic training mechanisms. The symposium will be of significant impact for the cognitive neuroscience community, offering new insights into the neural mechanisms involved in multisensory development, with important benefits for basic knowledge (how our multisensory neurons are fully adequate to experience) and for rehabilitative strategies in relevant patients populations.

Speakers:

- Benjamin A. Rowland, Ph.D. - Defects in multisensory integration produced by sensory deprivation: induction and recovery
- John J. Foxe, Ph.D. - The battle of the senses: A multimodal view of multisensory integration in autism
- Mauro Ursino, Ph.D. - Mechanisms for Bayesian inference maturation in a biologically inspired neuro- computational model
- Nadia Bolognini, Ph.D. - Multisensory integration in brain-damaged patients and its relation to functional recovery

Symposia Abstracts

Should binding and integration be synonymous?

Chairs: Sarah H. Baum, Ph.D., Ross Maddox, Ph.D.

In multisensory research we are interested in how and under what circumstances multiple pieces of sensory information coded across different sensory organs are combined. We often speak of multisensory processing in terms of “integration”, “binding windows”, and “fusion percepts”, for example, but exact definitions of these terms have not been widely adopted by the field. In this symposium we propose to discuss how we characterize different kinds of multisensory processing, including their associated behavioral and neural markers. From single cell recording through human psychophysics and neuroimaging, we will examine different perspectives on this issue and invite discussion amongst the speakers and attendees to better understand a topic central to our field.

Speakers:

- Sophie Molholm, Ph.D - Multisensory feature binding-- Deductions from high-density electrophysiological recordings in humans
- Ryan Stevenson, Ph.D. - Does the temporal binding window actually reflect “binding”? Evidence from clinical populations
- John Magnotti, Ph.D. - Reducing playback rate of audiovisual speech leads to a surprising decrease in the McGurk effect
- Jennifer Bizley, Ph.D. - Auditory-visual integration in auditory cortex promotes auditory scene analysis via multisensory binding

Symposia Abstracts

Supramodality and cross-modal plasticity in blindness: their balance and the implications for rehabilitation

Chairs: Emiliano Ricciardi, Ph.D., Olivier Collignon, Ph.D., Ella Striem-Amit, Ph.D.

This symposium brings together speakers who use different approaches to reveal how early blindness affects neural processing and enables rehabilitation. The research of our first three speakers will provide evidence for the balance between supramodal organization and cross-modal plasticity in the visual cortex of the blind. Ricciardi will present evidence for supramodality, the processing of information content regardless of the sensory modality through which a particular stimulus is conveyed, in the associative visual cortex. Collignon will discuss cross-modal plasticity, the change of the original visual function, in the earlier visual cortex. Striem-Amit will add evidence also for intact organization even in early visual cortex in the blind, despite these cross-modal changes. The next speaker will discuss rehabilitation in blindness in light of this organization, taking advantage of the use of compensatory cross-modal plasticity to overcome deficits caused by the absence of visual experience. Gori will discuss developing intact spatial cognition and orientation by extending the senses using audio feedback related to body movement. Finally, Bola will extend these principles of organization also to deafness, providing evidence for supramodality, task-specific organization, in the auditory cortex, suggesting these principles apply to the sensory cortices in general.

Speakers:

- Emiliano Ricciardi, M.D., Ph.D. - Supramodality and cross-modal plasticity as the "yin and yang" of (the blind) brain development
- Olivier Collignon, Ph.D. - How input modality and visual experience affect the functional response of the "visual" cortex
- Ella Striem-Amit, Ph.D. - Early sensory cortices in sensory deprivation – what remains of the original organization?
- Monica Gori, Ph.D. - Multisensory integration development for rehabilitation
- Łukasz Bola, M.A. - Task-specific reorganization of the auditory cortex in deaf humans

Symposia Abstracts

The development of multisensory space in early life: Perception, integration and attention

Chairs: Dorothy Cowie, Ph.D., Andrew J. Bremner, Ph.D.

The newborn human arrives into a startlingly complex multisensory spatial world in which it is inundated with information from touch, proprioception, vestibular input, audition, and vision, all of which provide information about objects and events, in uniformly varying spatial codes. The infant thus faces the daunting task of coordinating these different sensory spaces. The five talks in this symposium will report on recent findings regarding the development in early life (infancy and childhood) of multisensory spatial interactions underlying a range of cognitive abilities including spatial localization (Cappagli & Gori; Negen et al.), spatial attention (Thomas et al.), body awareness (Cowie et al.) and object representations (Orioli et al.). Overall, the talks indicate that a range of multisensory spatial links are in place by the middle of the first postnatal year. Orioli et al. report crossmodal effects of auditory cues to trajectory on visual ERPs in 5-month-old infants. Thomas et al. find crossmodal exogenous spatial interactions between touches and visual cues in 7-month-old infants. However, the extent to which crossmodal spatial links lead to optimal multisensory integration appears to develop later in childhood. The talks by Cappagli et al., Cowie et al., and Negen et al., address why optimal integration of multisensory space is early developing in some tasks, but not apparent until late childhood in others. They explore the roles of feedback and unisensory experience in multisensory spatial development, via training interventions and comparison of visually impaired and sighted children. The talks will be followed by a focused panel discussion.

Speakers:

- Giulia Orioli, Ph.D. - Effects of auditory trajectories (towards or away from the observer) on visual ERPs in 5-month-old human infants
- Rhiannon Thomas, Ph.D. - Multisensory attention in infancy and childhood: Exogenous crossmodal cuing effects between touch and vision in brain and behavior
- Dorothy Cowie, Ph.D. – Multisensory contributions to body awareness in childhood
- James Negen, Ph.D. - Learning Audio-Visual Cue Combination in Late Childhood via Feedback
- Giulia Cappagli , Ph.D. - Multisensory development of spatial localization skills in sighted and visually impaired children

Highlighted Student Research Abstracts

Both power and frequency of pre-stimulus alpha oscillations predict the temporal resolution of multisensory perception on a trial-by-trial basis.

London, R.E., Benwell, C.S.Y., Thut, G., Cecere, R., Quak, M., Talsma, D.

Alpha oscillations reflect fluctuations in attention and the excitability of the cortex. In particular, posterior alpha power predicts sensitivity to visual near-threshold stimuli and susceptibility to multisensory illusions such as the sound-induced flash illusion, whereas alpha frequency predicts the temporal resolution of both visual and audiovisual perception. In this study, we went beyond the detection of near-threshold or illusory stimuli and focused instead on the temporal resolution of audiovisual perception using a temporal order judgement task with simple auditory and visual stimuli, both well above threshold. Concurrently, we measured EEG for 40 participants. In this type of task, the behavioral measure of temporal resolution (the "just noticeable difference" or JND) is not obtained at each trial, but over a large amount of trials. By applying a jack-knife procedure adapted for linking single-trial activity to psychometric measures (Benwell et al., in prep.) we were able to calculate single-trial JND values and examine the co-variation of pre-stimulus activity and JND across trials. Single-trial pre-stimulus alpha power was calculated at each electrode for 23 frequencies from 1 to 45 Hz and for 51 time points from -1 to 0 sec. The JND was correlated with each of these values using the jack-knife procedure. Cluster-based permutation testing revealed that higher posterior alpha power is predictive of a higher JND, and thus a lower temporal resolution of audiovisual perception. In addition, we correlated the JND with single-trial instantaneous alpha frequency at 51 time points from -1 to 0 sec and found that higher posterior alpha frequency predicts a lower JND, and thus a higher temporal resolution of audiovisual perception. These results provide new insights into the role of attention and moment-to-moment fluctuations of cortical excitability in the temporal aspects of multisensory perception.

Increased neural strength and reliability at the boundary of peri-personal space

Jean-Paul Noel, David M. Simon, Antonia Thelen, Mark T. Wallace

The non-human primate brain counts with a dedicated fronto-parietal network comprising multisensory neurons that fire when stimuli are close to, but not far from the body. These neurons, thus, encode for the space surrounding and immediately adjacent to the body –

the peri-personal space (PPS). Although numerous fMRI studies have ratified the existence of a similar PPS system in the human brain, it is unknown what is the consequence of these neurons commencing to fire on larger neural ensembles. Further, although PPS is encoded by multisensory neurons, to date there has been no EEG characterization of the transition of unisensory as well as multisensory stimuli from within to beyond PPS. Here, thus, we present auditory, visual, and audio-visual stimuli both within and beyond participant's reach limit while recording continuous EEG. Results demonstrate a significant accentuation of global field power (GFP; i.e., strength of response) near but not far from the boundary of PPS, in particular for multisensory stimuli. The source of this GFP difference is localized to the intraparietal sulcus (IPS) and insular cortex. Further, approximately 70 ms beforehand the GFP difference (PPS boundary vs. non-boundary) there is a increase in evoked potential reliability, which is predictive on a subject-by-subject basis of the later on GFP difference. Together, our results indicate that the transition between near and far space is most marked for multisensory stimuli, dependent on neural reliability and strength, and highlight the hitherto neglected role of the temporal code in encoding for PPS.

The neurophysiological correlates of the rubber hand illusion: Effects on evoked potentials and event-related oscillations

Isa Rao, Christoph Kayser

Research funded by the Economic and Social Research Council. The rubber hand illusion (RHI) is used to induce the illusory feeling of ownership over a rubber hand through congruent multisensory stimulation. It is the most commonly used illusion to study how the brain resolves situations of conflicting multisensory information regarding the body's position. To identify the neurophysiological basis of the RHI, we acquired multichannel EEG of 20 participants during a modified RHI paradigm. Using a vibration pad on the participant's hand and an LED of similar size on the rubber hand, we acquired evoked potentials registered to the onset of visual and tactile stimuli duration during illusion and control conditions. Visual and tactile stimulation was either synchronous with an anatomically congruent (illusion condition) or incongruent (control condition) placed rubber hand. We furthermore tested the effect of varying the duration of the stimulus (100ms, 125ms, 150ms and 175ms). We found differences in evoked responses between the illusion and control condition in fronto-central areas around 330ms, as well

as an effect of stimulus duration. Due to their latency these ERP effects are unlikely to stem from processing in primary sensory areas but may reflect high-level integration processes in parietal cortex resolving the multisensory conflict in the illusion condition. In the time-frequency domain, we found a relative decrease in alpha and beta power in the illusion condition compared to the control condition. These results replicate findings from previous studies on body illusions and indicate an involvement of both alpha and beta oscillations in multisensory conflict resolution and/or in updating of the body representation.

Eye movement-related eardrum oscillations (EMREOs) suggest visual- auditory spatial integration begins in the auditory periphery

David LK Murphy, Kurtis G Gruters, David W Smith, Christopher A Shera, Jennifer M Groh

Visual and auditory signals that arise from coincident locations in space often fuse to produce a combined visual-auditory percept, such as lip reading cues that facilitate speech comprehension. A critical problem for this process is that the visual and auditory systems employ different methods of determining the locations of stimuli. The visual system uses retinal activation location and the auditory system evaluates interaural timing and intensity differences as well as spectral cues. In species that move their eyes with respect to the head, there is no fixed relationship between these cues, and representations must be adjusted with each change in eye position if the brain is to determine whether a visual and an auditory spatially coincide. Eye movements have been shown to modulate auditory activity in several brain regions such as the inferior colliculus, auditory cortex, parietal cortex, frontal eye fields, and the superior colliculus, but where eye movement-related signals first contribute to auditory processing is not known. One possibility is the auditory periphery. Outer hair cells, or motile neurons in the cochlea, and the middle ear muscles are under descending control from the brain, providing a possible route of transmission of information about eye movements to the auditory periphery. To test this hypothesis, we used a microphone to record movements of the eardrum in human subjects (n=10, 16 ears) performing saccades to visual targets. We found that the eardrums oscillated in conjunction with eye-movements, despite the absence of any delivered sound. These oscillations began at least 10ms before the start of any given saccade. The initial phase and magnitude of these eye-movement related eardrum oscillations (EMREO) was dependent on saccade origin, direction, and length.

This relationship suggests it contains the necessary information to facilitate visual-auditory spatial integration, although the exact means by which it does so remains uncertain.

Linear vection is enhanced by conflict between visual and non-visual cues to orientation

Meaghan McManus, Laurence R. Harris

When gravity cues are removed or become unreliable, visual information is weighted more strongly. Might a conflict between the body, gravity, and visual cues to upright reduce the reliability of the gravity cue and thus also enhance vision? In two separate experiments we introduced a visual reorientation illusion using virtual reality so that participants felt upright while the head, or head and body were physically tilted relative to gravity, and measured the effectiveness of optic flow in creating self-motion (vection). The conflict between visual and non-visual cues to upright was greater when both body and head were tilted compared to when only the head was tilted. Optic flow was presented in a head-mounted display with participants prone, upright or supine, or while standing with head tilted forwards, straight, or backwards. Participants saw a target at 10, 20, 40, 60 and 80m in a simulated hallway stretching away from their nose. The target was removed and the hallway accelerated past them. Participants pressed a button when they reached the remembered location of the target. Participants felt that they were standing upright and moving forwards horizontally in all conditions. Participants undershot the target distances (thought they travelled further) when supine and prone, relative to when upright and also with head bent forwards but not with head bent backwards. Lying supine or prone with visual cues indicating upright creates a conflict that allows vision to dominate as indicated by increased sensitivity to visually-induced self-motion. However, when the conflict is weaker (as when just bending the head), increased sensitivity was found only when the head was tilted forwards (not backwards). This difference indicates that increased visual sensitivity may depend not only on visual-vestibular conflict but may also be influenced by whether combinations of movement and posture are perceived as natural or purposeful.
Acknowledgements: LRH is supported by a Discovery Grant from the Natural Sciences and Engineering Research Council (NSERC) of Canada and the Canadian Space Agency. MM holds a research studentship from the NSERC CREATE program.

Highlighted Research Abstracts

Correlation between EEG and active haptic sensing implicates the visual cortex in tactile decision making

A key component of interacting with the world is how to direct ones' sensors so as to extract task-relevant information, a process referred to as active sensing, in order to optimize subsequent perceptual decisions. Here we investigated the neural underpinnings of active haptic sensing and decision making during a two-alternative forced choice reaction time task. We utilized a haptic device, called the Pantograph, to generate virtual grating texture with different amplitudes, and asked human subjects to actively sense and discriminate two virtual textures while their electroencephalograms (EEG) were recorded. To identify correlations between the EEG recordings and the subjects' active sensory experience, we used a novel methodology, termed EEG2Beh(aviour). This approach selects a spatial filter to apply to the neural response and a temporal filter to apply to the active sensing signals (position & velocity) such that the resulting filter outputs are maximally correlated in time. Hence, spatially filtered brain signals ("components") are matched with temporally filtered kinematic components. We found that an EEG component activating mainly occipital and frontal brain areas showed the highest correlation with the subjects' motor behavior. Interestingly, this component vanished during a control task identical to the decision-making task except the subjects were not required to discriminate the textures, suggesting the component is related to active processing of tactile information. EEG2Beh correlations of this component a) were negatively correlated with response times and b) scaled with task difficulty. To investigate which cognitive processes are represented by this component, we modelled the subjects' behavioral performance (discrimination accuracy and response time) using a hierarchical drift diffusion model. EEG2Beh correlations on each trial were significantly predictive of single-trial drift rates (positive correlation) and non-decision times (negative correlation). Taken together, these results suggest an occipital representation of tactile information processing during active haptic decision making

Cross-modal activation of visual cortices depends on auditory selective attention

Chrysa Retsa, Pawel J. Matusz, Jan Schnupp, Micah M. Murray

Salient sounds modulate the processing of visual stimuli via the orientation of exogenous attention towards the sound's location. Laterally-presented sounds can activate visual cortices, despite the sounds being task-irrelevant. However, it remains controversial

whether such cross-modal influences are automatic or contingent on stimulus-related and/or task-dependent processes. An auditory-evoked contralateral occipital positivity (ACOP) at ~250ms post-sound onset has been postulated as the event-related potential (ERP) correlate of this effect. It has been suggested that the cross-modal process indexed by ACOP is automatic. Our group has used a passive auditory paradigm to demonstrate that the ACOP is context-contingent. Specifically, the ACOP was observed when the sound's location was unpredictable, but not when the sound was predominantly presented to a given location. As in prior studies the ACOP was elicited by task-irrelevant sounds, our present study examined to what extent task-relevance, and specifically, selective attention to a given feature modulates the ACOP. To address this question, we employed an active auditory discrimination task and manipulated which one of four stimulus attributes (location, pitch, speaker identity, uttered syllable) was task relevant in each block. Sound acoustics were held constant across blocks, and their location was always equiprobable (50% left, 50% right). The only manipulation was which sound dimension participants were attending to. 128-channel ERP data from healthy participants were analyzed within an electrical neuroimaging framework. We show that presence of sound-elicited activations of visual cortices depended on the to-be-discriminated dimension. An ACOP was elicited only when participants were required to discriminate sound location, but not when they were attending to any of the non-spatial features. These replicate our prior results involving a passive paradigm to show that the ACOP is not automatic. Moreover, we extend these findings to show the interplay between task-relevance and spatial unpredictability in producing the cross-modal activation of visual cortices.

Real-world neuroimaging: Technologies for moving neuroscience beyond the laboratory

David Hairston

Decades of heavy investment in laboratory-based brain imaging and neuroscience have led to foundational insights into how humans sense, perceive, and interact with the external world. However, it remains unclear how experiences between laboratory-based and naturalistic human behavior may differ, leaving us with the unanswered question of how well the current knowledge of human brain function translates into the highly dynamic real world. To address this gap, in recent years ARL has developed a program on so-called "real-world neuroimaging", where the focus is on foundational research enabling a better understanding of brain function as it occurs in real-world contexts. This

overview talk will focus on two key aspects of this program which seem of highest relevance to the IMRF community. First, to provide context, I will highlight recent ongoing experimentation which targets neural (EEG) data collection in real-world scenarios (e.g. on-road driving; classrooms) or with induced real-life states (e.g. loaded walking; stress from being shot at)which suggest both the plausibility and challenges associated with this work. The second and primary aspect will be an in-depth description of technical advances to further these aims(e.g. artifact removal algorithms, dry sensors), and novel methods being used to validate them. For example, while our evidence shows that that blind-source separation techniques such as ICA are reasonably capable of removing motion artifacts, this is corroborated using a novel EEG "phantom" head device which replicates realistic EEG conductance to provide a previously unavailable ground-truth verification. Similarly, dry, non-metallic polymer electrodes and ultra-low power EEG DAQ systems hold the promise of easy field ability, but must be validated in creative, thorough manners to deal with the variability associated with human skin and the ionic-electronic interface problem. Together these aims hope to bridge both technical and scientific gaps hindering the understanding of sensory interactions as they truly occur in real life contexts.

Reframing variability: From nuisance to an aid to understand complex systems dynamics. Evidence from auditory, visual, and audiovisual timing tasks and simulations.

Boenke LT, Höchenberger R, Alais D, Ohl FW

Typically, variability is condoned as nuisance and widely unexplained. This also applies to audiovisual timing studies where inter-individual variability complicates interpretations, and across-study variability often yields contradictive results. While both, synchrony judgments (SJs) and temporal-order judgments (TOJs), have been employed in tasks measuring audiovisual simultaneity perception, the latter is in general found to show higher inter-individual variability than the former. The source of this difference is under debate. A fundamental difference between both tasks is, that while SJs can be achieved by focusing only on the temporal relationship of two stimuli, TOJs require focusing on an additional stimulus dimension (e.g. location, etc.) to perform the task. We hypothesized that the higher dimensionality of TOJs involves more complex neural networks, and that higher complexity of neural networks is accompanied by a larger number of possible network-states. When, under uncertainty, higher numbers of network-states are trial-wise

randomly realized, ceteris paribus, they are accompanied by higher variability. To test for this hypothesis, we performed a meta-study on SJ- and TOJ-tasks that have employed simple audiovisual stimuli, and plotted the average reported point of subjective simultaneity (PSS) as a function of the number of participants employed in each study. Subsequently, we performed a within-participant study including auditory, visual, and audiovisual SJs and spatialized TOJs. Besides instructions, tasks were otherwise identical. While the meta-study showed for both tasks (statistically indistinguishable) average PSS-values with a slight preference for the auditory modality, the across-study variability of PSS-values in TOJs was consistently larger than for SJs and in both tasks inversely related with the number of participants. In our study, TOJs showed for both modalities higher inter-individual variability for all observables. Finally, simulations supported our overall results to be compatible with the notion that differing number of possible network-states yields differing variability across-studies and between-individuals.

Processing of sound symbolic crossmodal correspondences

Krish Sathian, Kelly McCormick, Margaret Martinez, Sara List, Simon Lacey, Randall Stilla Lynne Nygaard

Crossmodal correspondences (CCs) occur between a variety of sensory stimuli (Spence, Attention, Perception & Psychophysics, 2011). For instance, tones of low and high pitch tend to be associated with, respectively, visual stimuli of low and high elevation or large and small size. Sound symbolism refers to CCs between certain sounds and visual shapes; e.g., the pseudowords “takete” and “maluma” are associated with spiky and rounded shapes, respectively. Such associations have been suggested to underlie the origins of language and to form a continuum with synesthesia (Ramachandran & Hubbard, Journal of Consciousness Studies, 2001), but little is known of how CCs, including sound-symbolic ones, are handled by the brain. In one experiment, we compared the sensitivity of synesthetes and non-synesthetes to CCs, using the implicit association test (Lacey et al., European Journal of Neuroscience, 2016). Three CCs were tested: (1) the auditory pseudowords “lomo” and “kike” (/lomo/; /kɛke/)paired with rounded and spiky visual shapes, respectively; (2) the pitch-elevation association and (3) the pitch-size association. Synesthetes exhibited stronger congruency effects than non-synesthetes for the sound-symbolic CCs, but not for the more basic CCs. Thus, at least for

synesthetes, sound-symbolic CCs appear to differ from basic CCs. In another experiment (unpublished), we examined the neural basis of sound-symbolic CCs using functional magnetic resonance imaging. The lomo-kike CC was associated with stronger responses for incongruent compared to congruent audiovisual stimuli, when the auditory stimuli were attended. These incongruency effects were found in and around the right intraparietal sulcus and in left frontoparietal areas. The right-sided effects co-localized with incongruency effects for audiovisual temporal synchrony and with magnitude estimation effects; the left-sided effects co-localized with stronger responses for auditory pseudowords than meaningful sentences. These findings suggest that sound symbolic CC processing may involve mechanisms related to both multisensory integration and phonological decoding. Supported by NEI

Hallucinations result from overweighting of perceptual priors

Albert R. Powers, Christoph Mathys, Philip R. Corlett

It has become increasingly clear that perceptual systems, rather than relying wholly upon information coming from sensory organs like the retina and the cochlea, instead blend this input with perceptual beliefs about the sensory environment. We sought to test the hypothesis that hallucinations (percepts in the absence of external stimulus) may be seen as an over-weighting of these perceptual beliefs when combined with sensory evidence during perceptual inference. We employed sensory conditioning to elicit hallucinatory experiences via traditional learning mechanisms: in a functional imaging experiment, participants were exposed to repeated pairings of visual and auditory stimuli and subsequently perceived the presence of the auditory stimulus when only the visual was present. We applied this Conditioned Hallucinations paradigm to four groups of participants: those with psychosis both with (P+H+) and without (P+H-) hallucinations, otherwise healthy voice-hearers (P-H+), and healthy controls (P-H-). We found that conditioned hallucinations readily occur in all subjects but with markedly increased frequency in those who hallucinate (P+H+ and P-H+) compared to their non-hallucinating counterparts. Conditioned hallucinations were characterized by increased engagement of tone-responsive auditory cortex in addition to a network of brain regions previously identified in symptom-capture-based studies of hallucinations. This network included anterior insula, association auditory cortex, posterior superior temporal sulcus, head of caudate, cerebellum, and hippocampus. We then employed a computational approach

that formally models perception as a combination of prior belief and sensory input: a three-tiered Hierarchical Gaussian Filter (HGF). HGF model parameters signifying the weight perceptual beliefs exert during perceptual inference were found to be increased in those with hallucinations (P+H+ and P-H+). In contrast, all those with psychosis (P+H+ and P+H-) exhibited differences in higher-level model parameters; specifically, they were less likely to detect changes in how much the visual stimulus predicted the auditory stimulus when compared to non-psychotic participants. We then regressed fitted perceptual belief trajectories onto participants' brain responses. We found that the anterior insula and superior temporal sulcus correlate with perceptual beliefs, while the cerebellum and hippocampus may encode the volatility of those beliefs. Overall, these results may represent an objective means to discern people with hallucinations from those without, and, orthogonally, a need for treatment from those without.

Poster Abstracts

#101 Multi-modal ongoing activity modulation in temporal cross-modalities adaptation of audition and vision

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Recent studies of interactions between sensory systems have highlighted different benefits as the perceptual advantages of combining information from auditory-visual modalities. Here we tested whether the bimodal system's time processing is the same in case of opposite audio-visual (AV) and (VA) passive lag-adaptation paradigm. For this we investigated phase differences of measured auditory and visual Local Field Potentials (LFPs). We compared their measures of synchronization and variability, before and after adaptation using two opposite asynchronous stimuli. Systematic changes in the phase of ongoing neural oscillations were observed. The results show that adaptation yields significant phase variability decrease and phase shift to synchronization of ongoing activity, independently from the stimulus direction: auditory first (AV) or visual first (VA) with fixed 200 ms SOA. We suggest that bimodal auditory-visual adaptation gives rise to: 1) ongoing process of functional reorganization, 2) active neural compensation in the encoding of sensory event and 3) neural ongoing activity has dynamics response independent from the adapter direction.

#102 Impaired localisation and visuo-motor integration in Complex Regional Pain Syndrome

Janet H. Bultitude, Karin Petrini

Complex Regional Pain Syndrome (CRPS) is a condition of chronic pain and other symptoms in a limb that may be partly driven by cortical changes. Patients have problems with spatial processing, e.g. locating their affected limb or attending to touch on the affected side of space. Also, pain can be exacerbated by loud noises and ambiguous visual stimuli, suggesting changes in multisensory integration. We investigated localisation and multisensory integration in 14 CRPS patients (7 upper, 7 lower limb) and 17 controls.Targets appeared briefly on the left or right side of a piece of paper positioned on a table (10 trials/side). Participants indicated the location of the targets under three conditions: 1)Visual-only (V): indicating through verbal directions

where the target had appeared; 2)Proprioceptive/Motor-only (P/M): touching the target's location without vision; 3)Combined Visual-Proprioceptive/Motor (V-P/M): touching the target's location with vision. Participants completed the P/M and V-P/M blocks once each with their left right hands. Estimates of variable error (VE: the sum of the variance of the points in x and y directions) were calculated separately for each condition.6/7 upper and 6/7 lower limb patients had VEs in at least one condition that were larger than the upper bound of the 95% confidence interval for the control data, suggesting localisation deficits. Paired comparisons of group data showed that for control participants the VEs in the V-P/M condition were lower relative to both the V and P/M conditions (ps=.0005), consistent with reduced variability during multi- compared to uni-sensory guidance. Patients' VEs in the V-P/M condition were not significantly different to VEs in the V condition (p=.62) nor the P/M condition (p=.27), suggesting an integration deficit. Since deficits were shown by upper and lower limb patients, these changes are not limited to tasks involving the affected limb but generalise to broader spatial cognition.

#103 The system to provide a user an artificial oculomotor function to control directions of gaze and zooming-in/out of both of eyes independently

Fumio Mizuno, Tomoaki Hayasaka, Takami Yamaguchi

In previous work, we got an idea from characteristics of visual behavior of chameleons which they move their both of eyes independently and developed a wearable system to give independent fields of view to both eyes of a human user. The system is the robotic system to control postures of two CCD cameras and a head-mounted display (HMD). The user could get two independent fields of view by controlling two cameras with use of two sensors set to both of hands. HMD projected two images taken by each camera onto each eye independently in real time. We conducted experiments on visual search to investigate human performance while using the system. The results showed that response times of behavior of the users were delayed up to 134.9%, though they could look around and distinguish independent views. While using the system, binocular rivalry occurred to the users. It is assumed that the amount of information brought by perceiving two independent fields of view was depend on timing of perceptual alternation induced by binocular rivalry. The perceptual alternation is affected by visual stimuli including images projected on to both of eyes. It was possible that successful users whose decline of response time to the task was low could control postures of cameras to

generate visual stimuli induced by postural changes of cameras skillfully. Here, image motions caused by camera movements are only linear. Therefore, we focused on zoom-in/out of a camera because zoom of images induces radiate image motion and change of spatial resolution. In this work, we developed the system to provide independent fields of view by installing cameras equipped with electronic controllable zoom lens. In future work, we will conduct experiments to investigate effects of implementation electronic control zoom and the human performance of the user.

#104 Cognitive and sensory load modulates gait and electrocortical activity during treadmill walking

Brenda R. Malcolm, John J. Foxe, John S. Butler, Sophie Molholm, Pierfilippo De Sanctis

To efficiently navigate complex environments the brain must continuously adapt in response to fluctuating visual, somatosensory and vestibular inputs. However much remains unknown regarding the underlying cortical sensorimotor mechanisms involved in maintaining steady locomotion. Here, we employed a Mobile Brain/Body Imaging (MoBI) approach, synchronously recording EEG and 3D body motion tracking, to assess the effects of cognitive and sensory load on locomotion. Sixteen participants (mean age = 26 years) walked on a treadmill in front of a full field optical flow display while motion capture recorded kinematics of the head and feet. Effects of cognitive load were assessed by performing a simple Go/No-Go task while walking. Sensory load was manipulated by presenting three optical flow conditions: a star-field moving in accordance with walking speed, moving with periodic mediolateral perturbations, and a static star-field (control condition). Participants walking while engaged in the cognitive task exhibited increased stride length variability but reduced postural displacement in the mediolateral and anterior-posterior directions. Visual perturbations primarily affected gait in that average step width and stride length variability increased with increasing disruptions to the visual field. Oscillatory cortical activity implicated in the control of gait was evaluated with event-related spectral perturbations time-locked to foot falls. We focus on intra-stride spectral power modulations in the theta (4-7Hz), mu (8-13Hz) and beta (15-25Hz) bands, localized to sensorimotor and parietal cortex. Our results provide insight into the neural correlates of gait control, and may be relevant to fall-prone older adults who are less able to flexibly adjust to ongoing cognitive and sensory demands while walking.

#105 Audio-visual multiple object tracking

Vanessa Harrar, Eugenie Roudaia, Jocelyn Faubert

The ability to track objects as they move is critical for successful interaction with objects in the world. The multiple object tracking (MOT) paradigm has demonstrated that, within limits, our visual attention capacity allows us to track multiple moving objects among distracters. Very little is known about dynamic auditory attention and the role of multisensory binding in attentional tracking. Here, we examined whether dynamic sounds congruent with visual targets could facilitate tracking in a 3D-MOT task. Participants tracked one or multiple target-spheres among identical distractor-spheres during 8 seconds of movement in a virtual cube. In the visual condition, targets were identified with a brief colour change, but were then indistinguishable from the distractors during the movement. In the audio-visual condition, the target-spheres were accompanied by a sound, which moved congruently with the change in the target's position. Sound amplitude varied with distance from the observer and inter-aural amplitude difference varied with azimuth. Preliminary results with one target showed that performance was better in the audiovisual condition, which suggests that congruent sounds can facilitate attentional visual tracking. However, with multiple targets, the sounds did not facilitate tracking, suggesting that audiovisual binding may not be possible when attention is divided between multiple targets.

#106 Repeated (but not incremental) training enhances cross-modal recalibration in the ventriloquism aftereffect

Patrick Bruns, Brigitte Röder

After exposure to synchronous audiovisual stimuli with a consistent spatial disparity, unimodal auditory localization is usually shifted in the direction of the visual stimuli. This cross-modal recalibration of auditory localization (known as the ventriloquism aftereffect) has been shown to emerge rapidly, with no further increase in the size of the aftereffect beyond an audiovisual exposure duration of about 3-5 minutes. However, it is well-known that perceptual learning effects might benefit from consolidation after training. We therefore tested whether or not repeated training with spatially disparate audiovisual stimuli would result in an increase of the ventriloquism aftereffect over sessions. Moreover, we tested whether or not an incremental training, in which the audiovisual

spatial disparity increases over sessions, is more effective than repeated exposure to a consistently large disparity. Participants (n = 20) were randomly assigned to one of two groups. In the first group, the degree of audiovisual spatial disparity increased over the course of three days. On day 1, visual stimuli were always displaced by 4.5 degrees to the right of the auditory stimuli. The disparity increased to 9 degrees on day 2, and to 13.5 degrees on day 3. The second group was only exposed to the largest disparity (13.5 degrees) during all three sessions. Post-adaptive sound localization was significantly shifted toward the right after completion of training, that is, a ventriloquism aftereffect was observed in both groups. However, incremental learning did not enhance cross-modal recalibration. Rather, the size of the ventriloquism aftereffect was larger in the constant learning group, due to an increase over days. Thus, repeated exposure to a consistent audiovisual spatial disparity enhanced cross-modal recalibration beyond the maximum amount of recalibration reached within one session, suggesting that recalibration effects were partly retained across sessions despite spatially coincident audiovisual stimulation outside the laboratory between sessions.

#107 Investigating the multisensory perception of freshness in beverages: The case of audio-visual interactions

Jérémy Roque, Jérémie Lafraire, Malika Auvray

Despite the abundant literature on flavor perception in cognitive science, research on the topic is still in its early stages when it is applied to particular instances of flavor such as freshness. Freshness has received recent consideration in consumer studies due to its hedonic dimension, which in turn may influence consumers' behavior. Beyond this aspect, little is known about the nature of the perceptual and cognitive mechanisms underlying freshness perception. To investigate the extent to which freshness results from multisensory integration, we conducted a study exploring the influence of audio-visual interactions on freshness perception and categorization. To do so, 84 participants were asked to assess the perceived freshness intensity for a given beverage on a 9-point Likert scale. The audio-visual stimuli were included in a fully factorial design varying temperature, carbonation, as well as the color of the liquid. The experiment was conducted through an internet-based testing tool (QualtricsÂ©) recording participants' reaction times. In addition, to confirm and extend the results of the internet-based experiment, the same experimental design was conducted in a laboratory setting using E-

prime. In this condition, the participants were requested to categorize each bimodal stimulus presented as being “Fresh” or “Not fresh”. We discuss the results of these experiments in terms of the potential crossmodal correspondences mechanisms at stake between the different perceptual features belonging to the freshness category, potentially leading to freshness enhancement.

#108 Dance and neurorehabilitation quantified using neuroimaging: rsEEG & fMRI

Rebecca Barnstaple, Debora Rabinovich, Remy Cohan, Karolina Bearss, Rachel J. Bar, Jasmine Morrison, Joseph F.X. DeSouza

Dance or movement to music is an intensively multimodal activity, engaging both top-down and bottom-up brain processes (Bar & DeSouza, 2016). Dance simultaneously involves memory, visual-spatial awareness, kinesthetic and vestibular information, motor imagery, touch, imagination, timing, and musical/social elements, challenging the central nervous system (CNS) in novel and stimulating ways (Dhami, Moreno & DeSouza, 2015). In many cultures, dance has played a role in health and well-being; fostering integration of multisensory stimuli and coordinating both inter/intra personal responses, dance nurtures plasticity and neurorehabilitation. Multiple cognitive and sensorimotor improvements have been measured as a direct result of involvement in dance by the elderly (Kshtriya et al 2015; Westheimer et al 2008; 2015). Our group uses EEG and fMRI to investigate neural processes involved in dance, specifically looking at learning and therapeutic effects over time (DeSouza et al 2012; 2013; Levkov et al 2014; Barnstaple & DeSouza, 2016; Rabinovich et al 2017). Working at multiple locations and with diverse approaches, we are measuring the effects of dance participation for Parkinson's disease (PD), mood disorders, and chronic pain. Results show improvements in balance, gait, and depression scores for PD, as well as lateralized differences in alpha power: Pre-class, alpha was observed to be lateralized towards the right hemisphere in pilot data for a group with depression, and this lateralisation effect diminished post-class (8-weeks later). Our data thus far provide initial evidence for neurobiological changes associated with dance; future research will focus on decomposing multisensory aspects of the stimuli involved (such as music, touch, vision, social interactions).

#109 Haptic information facilitates audiovisual size perception in children but not adults: an ERP study in support of the developmental cross-calibration theory

Meike Scheller, Sara Garcia, Joe Bathelt, Michelle De Haan, Karin Petrini

Several behavioural studies have shown that, while adults integrate sensory information in a statistically optimal fashion, children as old as 8- 10 years exhibit sensory dominance. When discriminating object size for example, young children rely more on haptic than visual or auditory information (Gori et al., 2008; Petrini et al., 2014). However, evidence in support of this sensory dominance at the neural level is scarce. Here we present an ERP study looking at the differences in multisensory processing between children and adults using active touch to perceive object size. We asked 10 adults and 10 children to attend to a wooden ball stimulus while we recorded their neural activity using electroencephalography (EEG). They either had to listen to the sound of the ball, passively look at the ball being tapped while listening to its sound or look at and actively tap the ball while listening to its sound. Here, the sound either matched the size of the presented ball (congruent, e.g. big ball with loud sound) or not (incongruent, e.g. small ball with loud sound). A temporal analysis of ERPs at the mid- parietal channels revealed significant differences in processing patterns between adults and children. We found a significant interaction of age and congruency in the P2 (area and peak amplitude), N2 (area and peak amplitude), and N1 (peak amplitude) components when active touch was involved. When no active touch was involved we found a significant interaction only in the P2 component. The results indicate that touch facilitates object size perception in children by reducing the level of neural activity only in this group when audio and visual information disagreed. These findings support Gori et al.'s (2008) cross-calibration theory by which the more robust sense in a given task (touch here) calibrates the less robust senses in young children.

#110 Can lexical retuning of perceived segments transfer across modalities?

Sharon Chee, Josh Dorsi, Lawrence D. Rosenblum

There is evidence that phonetic categories are 'retuned' after hearing an ambiguous segment in a disambiguating context. For example, replacing the final /f/ sound in a word such as “Witlof” (Dutch for “Chicory”) with a sound ambiguous between /s/ and /f/ made participants more likely to subsequently categorize items from a /f/-/s/ continuum

as /f/ (Norris, McQueen, Cutler 2003). This effect can also be found using simultaneous presentation of an additional modality to disambiguate the /?/, such as adding a clear visual (lipread) /s/ or /f/ (e.g. Vroomen & Baart, 2009), and clear auditory speech has even been found to subsequently retune ambiguous visual speech segments (Baart & Vroomen 2010). However, while research shows that one modality can act as an disambiguating context for another, it is unknown whether the retuning that occurs in one modality can be transferred to the other modality (but see, Dias & Rosenblum, 2016). This study explores whether the retuning of a visual segment (from a sentence context) also retunes the same segment when presented auditorily. Participants identified items from an 11 step acoustic continuum ranging from 'fat' to 'sat', before and after viewing silent videos of a speaker saying sentences containing sentences containing “/?/at” (as in “sat” or “fat”). Retuning is measured by comparing continuum identifications pre and post visual sentence presentation. Initial results suggest that some effects of retuning can be transferred crossmodally, and will be discussed in the context of the Supramodal Learning Hypothesis (Rosenblum, et al. 2017).

#111 Interaction and manipulation of dynamical virtual content by visually impaired people

Mariacarla Memeo, Giulio Sandini, Luca Brayda†

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During rehabilitation, visually impaired subjects are passive agents of exercises with fixed environmental constraints. In fact in a printed tactile map, which is a particular picture with a specific spatial arrangement, information cannot be edited by users. Interactivity instead facilitates the usability of printed tactile maps and the learning of spatial skills. The possibility to actively handle the components of a layout requires to exploit mental imagery resources to plan a strategy for solving a task and to constantly update mental representation of the content after modifying it. This process is more challenging since it involves a kind of understanding committed to a successive manipulation. Additionally, when the learning process aims at teaching 'how to' develop a certain knowledge, memory functions in a way that facilitates the recall and use of such knowledge. This study aims at understanding if visually impaired people can exploit their imagery to interact with virtual content and actively manipulate it by means of a novel

haptic device. The experiment consisted in changing the position of pre-existing elements with the goal of creating a new and more complex object. Participants were accurate in solving the task since they successfully completed it 90.5% of times. Importantly, results showed that accuracy is predicted by the efficiency of participants, through a positively linear relationship: the more the participants were able to carefully choose the number of moves, the more they performed well. The measure of efficiency can be a sufficient variable to evaluate, in a post-test analysis, the trend of a rehabilitation protocol. Furthermore, the gender modulated the execution time showing that men were faster than women in accomplishing the task. This information is crucial to tune exercise protocols according to each user during the learning phase in a rehabilitation scenario.

#112 Preferences for surface and structural properties in mental imagery: A multisensory organizing principle

Simon Lacey, Lokita Rajan, K. Sathian

Individual differences in both visual and haptic imagery can be organized along a continuum of preferences for object and spatial imagery subtypes. Object imagers tend to integrate surface properties, such as color and texture, with structural information about shape. By contrast, spatial imagers tend to ignore surface properties and instead focus on structural information and spatial transformations. Here, we tested the hypothesis that there are corresponding subtypes of auditory imagery. Participants (n=25) listened through earphones to 12-tone sequences in which each tone (of constant pitch and duration) varied in loudness and whether it was played in the right or left channel. The task was to discriminate the spatial pattern (a structural property) across changes in the loudness pattern (a surface property) and vice versa. Poor discrimination of the spatial pattern across loudness changes would indicate integration of structural and surface properties and reflect the auditory equivalent of object imagery. Poor discrimination of the loudness pattern across changes in the spatial pattern would indicate that surface properties were not attended and reflect the auditory equivalent of spatial imagery. Participants' imagery preferences were classified by their scores on the Object-Spatial Imagery and Verbal Questionnaire, a measure of visual imagery preferences. Consistent with our visual and haptic studies, we found that differences in auditory performance tracked participants' visual imagery preference: object imagers could not discriminate the structural property over a change in the surface property while

spatial imagers could not discriminate the surface property if the structural property changed. We conclude that the propensity to integrate surface properties into an image (object imagery) or to favor structural properties (spatial imagery) is a multisensory organizing principle of mental imagery across the three modalities of vision, haptics, and audition.

#113 Asymmetric bias in perceived finger orientation across hands in right-handers, but not left-handers

L.E. Fraser, L.R. Harris

Introduction: In the absence of vision, right-handers' perception of finger orientation is biased towards different axes for the right and left hands in the horizontal plane (~2Â° and ~25Â° inwards, respectively, Fraser and Harris, 2016). Here we tested if this pattern was also found in left-handers and whether orientation errors vary with lateral hand displacement relative to the midline. Method: Left- (n=21) and right- (n=20) handers sat with their index finger attached to a rod mounted on a stepper motor that rotated the finger about the middle knuckle parallel to the table surface. A mirror blocking the participants' view of their hand optically superimposed a line on the unseen finger's position. The motor rotated the participant's finger to a test orientation (stopping briefly at three distractor positions), and participants then rotated a line to match the perceived orientation of the finger. Seven orientations (30Â° outwards to 30Â° inwards) were tested 8 times at three hand positions: aligned with the body midline, aligned with the ipsilateral shoulder, or at twice the midline-to-shoulder distance on the ipsilateral side. Results: Right-handers showed an asymmetric pattern of finger orientation biases between hands consistent with previous findings, however left-handers did not show such an asymmetry. Left-handers were most accurate when either hand was aligned with the shoulder, as were right-handers for their left hands. But right-handers were most accurate in judging the position of their right index finger when the right hand was aligned with the midline. Conclusion: Right-handers show hand asymmetry in finger orientation perception, likely related to the functional specialization of the dominant and non-dominant hands; left-handers appear to be less lateralized in this respect.. Both left- and right-handers' errors depend on the position of the hand relative to the shoulder.

#114 Audio spatial memory and visual experience

Walter Setti, Luigi F. Cuturi, Monica Gori

Spatial memory in children can be a multimodal representation of the environment and can be mediated by different sensory signals. The role of the auditory modality on spatial memory process and the role of the visual experience on it are not yet clear. Here we investigate how the auditory modality influences memorization, contributing to the mental representation of a scene. Our aim was to verify if semantic rather than non-semantic sounds are better recalled in memory test and if learning an auditory scene can enhance spatial memorization. An auditory spatial memory test was performed by 12 sighted and 12 blind children (6-17 years). The setup was made up of a surface composed of 5x5 loudspeakers, covered by tactile sensors. The experiment consisted of a pre-test and post-test phase, interleaved by a training phase. In the first and last phase, the child had to listen to sequences of sounds and touch the device in the position where the sounds, spatially displaced, appeared to originate. During the training, subjects could explore the device surface while listening to sounds from the speakers activated after each touch. Semantic and non-semantic sounds were presented in separate sessions. At the end of the semantic test, subjects were asked to rebuild the scene created with the combination of semantic sounds. Our findings show an improvement in the semantic condition, in both blind and sighted subject's performance after the training. This result suggests that memorization for the spatial locations of nameable sounds is better than for non- nameable stimuli. Interestingly, we observed a positive correlation between memorization improvements and accuracy in reconstructing the scene only in sighted children older than 8 years. We discuss these results in terms of the role of visual experience on spatial memorization and on different reference frame between sighted and blind children.

Poster Abstracts

#115 Intracranial EEG signatures of the sound-induced flash illusion

Erin M. Yeagle, Pierre Mégevand, Manuel Mercier, Matthew T. Kaufman, Lital Chartarifsky, Sashank Pisupati, Anne K. Churchland, Ashesh D. Mehta

presenter: Jose Herrero

The ability to combine information from different sensory modalities to inform decision-making is a critical component of cognition. To illuminate neural underpinnings of this ability in humans, we employed a multisensory illusion, the sound-induced double flash illusion (Shams et al. 2000). In this illusion, auditory beeps impact the perception of a single visual flash. Neural correlates of the illusion have been identified in visual cortex, but the precise source of the illusory percept remains undetermined.We collected intracranial recordings from depth electrodes implanted in four subjects with refractory epilepsy undergoing presurgical evaluation. Subjects were presented with flashes and beeps, either congruent (one flash and one beep) or conflicting (one flash two beeps) and they reported the number of flashes perceived. Intracranial EEG was recorded throughout the task. As in healthy subjects, epilepsy patients perceived the sound-induced double flash illusion more frequently in trials with shorter delays to the second beep (SOA). For analysis of neural signals, we selected the SOA that most closely produced 50% illusory perception in each subject. As a signature of the illusion had previously been reported in early visual cortex, we focused our analysis of intracranial recordings on electrodes in that area, comparing event-related potential (ERP) and high gamma power (HGP) in trials when subjects reported perceiving the illusion and trials when they did not. We found no significant difference in either ERP or HGP in early visual cortex electrodes. However, we did identify candidate generators of the illusion in HGP in higher-order areas, including extrastriate visual cortex and superior temporal cortex. Our analysis suggests that the signature of the sound-induced flash illusion does not lie in early visual cortex. Rather, the illusion is likely supported by computations in a network of higher-order sensory and multisensory areas.

Poster Abstracts

#116 Audiovisual stimulus correlation drives multisensory perceptual decisions

Aaron R. Nidiffer, Ramnarayan Ramachandran, Mark T. Wallace

Sensory signals originating from the same event, such as the voice and mouth movements of a speaker,are often temporally correlated. It is hypothesized that the brain evaluates these correlations to facilitate feature integration and binding within and across sensory modalities. Previous studies have shown that correlation between unisensory signals facilitates several multisensory behaviors, whereas uncorrelated signals do not. In the current study, we sought to further illuminate the nature of this relationship, hypothesizing that multisensory behavior will vary with the strength of correlation. To this end, we presented participants with sinusoidal amplitude modulated auditory and visual stimuli at modulation depth thresholds. Participants reported the presence or absence of modulation in either stimulus. On a trial, modulation was present in auditory, visual, both, or neither modality (20% of the total trials, catch trials). On audiovisual trials, visual modulation frequency and phase were constant while auditory modulation frequency and phase were varied to generate stimulus pairs with a range of temporal correlations. Accuracy and reaction time data were fit to a drift diffusion model in which non-decision time and drift rate could vary across conditions. The pattern of discriminability and drift rate across conditions was very similar to that of stimulus correlation, but with an apparent phase shift that reflected unique temporal processing of the unisensory stimuli across participants. After accounting for this phase shift, drift rate varied with stimulus correlation in every participant, suggesting that stronger stimulus correlations provide stronger sensory evidence. In two participants, non-decision time decreased with increased stimulus correlation indicating faster encoding of positively correlated stimuli. These results indicate that the degree of stimulus correlation strongly impacts multisensory perception. Further, they suggest that the process of binding could be stochastically dependent on correlation such that signals are more likely to be bound as their correlation approaches 1.

#117 Integration and error processing of asynchronous audiovisual speech

David M. Simon, Aster G. Samuel, Mark T. Wallace

Auditory speech signals are highly ecologically important and ubiquitous in the everyday environment. Due to the obligatory nature of mouth movements in producing these

valuable acoustic inputs, visual speech is temporally correlated with the acoustic signal and thus carries substantial information about the auditory signal envelope. Combining these separate inputs to form a coherent speech representation through multisensory integration is known to offer substantial perceptual benefits in challenging acoustic conditions. Previous work characterizing this process has found that event related potentials (ERPs) to auditory speech are both temporally accelerated and diminished in magnitude by the presence of visual speech. We sought to determine the dependency of this suppression effect on synchrony between the auditory and visual speech streams using a combination of electroencephalography (EEG) and speech signals in which we manipulated the onset time of the auditory and visual streams. We found that suppression of ERP amplitude is maximal when the visual signal precedes the auditory signal by a small amount, and that increasing amounts of asynchrony reduce interactions in a continuous manner. Time-Frequency analysis revealed that effects are present primarily in the theta (4-8 Hz) and alpha (8-12 Hz) bands, with a central topography consistent with auditory generators. Theta effects were also found to persist far longer in the lower portion of the theta band (3.5-5 Hz), and this late theta activity was more frontally distributed. Crucially, the magnitude of these late frontal theta oscillations not only differed with the temporal characteristics of the stimulus, but predicted participant task performance. Our analysis thus reveals that suppression of single trial brain responses by visual speech depends on the temporal synchronization of sensory inputs and establishes error processing in the lower theta band as a neural correlate of individual differences in multisensory temporal perception.

#118 Action-effect contingency modulates readiness potentials

Tiziana Vercillo, Sean O'Neil, Fang Jiang

The brain is a predictive machine that constantly anticipates events in the world and then combines expectations with the incoming sensory signals to generate reliable percepts. It has been suggested that predictive processing originates from the motor system and that incoming sensory inputs can be altered to minimize prediction errors. However, a clear neural marker that links premotor cerebral activity with top-down predictions is still missing. In the current study, we investigated the role of the readiness potentials, i.e. the premotor brain activity registered within the fronto-parietal areas, in sensory-motor binding. We recorded EEG data while participants were performing a

motor task where a simple motor action such as a button press was required, a visual task where a visual stimulus was presented on the screen, and a visuomotor task where the visual stimulus appeared only in response to a button press. We measured evoked potentials before the motor action and after the appearance of the visual stimulus, and compared latency and amplitude of these ERPs across experimental conditions. Attending a visual feedback in response to a voluntary action modulated the amplitude of the readiness potentials. Moreover, the most negative peak preceding the onset of the movement was delayed by ~120 ms in the visuomotor condition as compared to the motor condition. We also found a reduction in the amplitude of the visual P200 for the visuomotor condition in the frontal regions indicating sensory suppression. Our results suggest that premotor brain activity might reflect predictive processes in sensory-motor binding and that the readiness potentials might represent a neural marker of these predictive mechanisms.

#119 Spatial modulation of sensory-motor processing in early deaf individuals

Tiziana Vercillo, Fang Jiang

Audition dominates other senses in temporal processing, and in the absence of auditory cues, temporal perception can be compromised. Moreover, after auditory deprivation, visual attention is selectively enhanced for peripheral visual stimuli. In this study, we assessed whether early hearing loss affects motor-sensory recalibration, the ability to adjust the timing of an action and its sensory effect based on recent experience. Early deaf participants and hearing controls were asked to discriminate the temporal order between a motor action (a keypress) and a visual stimulus (a white circle) before and after adaptation to a delay between the two events. To account for spatial asymmetries in visual attention, we presented visual stimuli in both central and peripheral visual fields. Results showed overall higher temporal thresholds for deaf participants as compared to hearing controls, suggesting that the auditory information is important for the calibration of motor-sensory timing. Adaptation to a motor-sensory delay induced distinctive effect in the two groups of participants, with hearing controls showing a recalibration effect for central stimuli only whereas deaf individuals for peripheral visual stimuli only. Using EEG, we tested whether the spatial modulation of motor-sensory processing derives from asymmetriesin allocating attentional resources. EEG data did not revealed a spatial modulation of visual evoked responses across the two group of

participants.Nevertheless, we found dissimilarities between deaf and hearing individuals in premotor brain activity,the readiness potentials, with spatially inducedopposite patterns of activation. These results suggest that auditory deprivation affects motor-sensory processing. Moreover, the attentional differences in premotor processing between deaf and hearing individuals may possibly contribute to the dissimilaritywe foundin the spatial modulation of motor-sensory recalibration.

#120 The relationship between eye movements and the McGurk effect when stimuli are degraded in noise

J.E. Stacey, C. Howard, S. Mitra, P.C. Stacey

Everyday conversations rely on the ability to combine auditory speech (the talker's voice) and visual speech (the talker's face). The McGurk effect (McGurk & MacDonald, 1976) is a long established method for testing audiovisual (AV) integration. When the auditory syllable 'ba' is combined with an incongruent visual syllable 'ga' the listener hears a third syllable e.g. 'da'. Differences in where people look at a face may affect how often the McGurk effect is perceived (Gurler et al., 2015). One study found that people who perceived the McGurk effect more frequently directed more of their gaze at the mouth region compared to those who perceived the McGurk effect less frequently (Gurler et al., 2015). Other studies (e.g. Paré et al, 2003) report that fixating on the mouth did not predict the McGurk effect. Time spent fixating on an area may vary according to the level of auditory degradation in the stimuli; Buchan, Paré, and Munhall (2008) found that fixations on the mouth increased in auditory noise, while Wilson et al. (2016) found fixations on the mouth decreased with decreasing visual resolution. The current experiments aimed to build on previous findings and ascertain a) where people look when stimuli are degraded by both auditory and visual noise and b) whether looking at the mouth predicts the McGurk effect. Participants (n=37) viewed congruent and McGurk stimuli in different levels of auditory and visual noise. Preliminary results show that as expected, participants looked at the mouth more on trials when the McGurk effect was perceived. McGurk responses as well as fixations on the mouth increased as auditory noise increased but decreased as visual degradation increased. The findings add to our understanding of the benefit of visual information when (auditory and visual) speech is degraded and could have potential implications for people with auditory/visual impairments.

#121 Prior information on audiovisual correspondence affects visual perception outside of awareness

Hyun-Woong Kim, Chai-Youn Kim

Previous studies have suggested that a visual stimulus gains its enhanced access to visual awareness under interocular suppression when accompanied by congruent auditory inputs (Alsius & Munhall, 2013; Cox & Hong, 2015). The current study explored influence of prior information about temporal correspondence of audiovisual stimuli on the subsequent processing of those outside of visual awareness. On each trial, observers viewed a ball-shape object bouncing within a rectangular window for a few seconds before it was rendered invisible by continuous flash suppression (CFS; Tsuchiya & Koch, 2005). Observers were instructed to press a button when they detected the ball breaking through suppression. The ball was presented with clicking sounds, which were temporally matched (congruent, C) or unmatched (incongruent, I) to bounces of the ball. The temporal synchrony was independently manipulated preceding (prior congruency) and following (trial congruency) the onset of CFS, comprising four different conditions. Repeated measures ANOVA showed that only the main effect of trial congruency was significant, indicating that the bouncing ball accompanied by temporally matched sounds (C-C and I-C trials) was detected faster than that accompanied by temporally unmatched sounds (C-I and I-I trials) regardless of prior audiovisual congruency. However, further correlation analysis unveiled individual differences according to prior congruency: individual detection advantages by trial congruency associated with congruent prior information (difference in mean detection time: C-I minus C-C trials) were negatively correlated with those associated with incongruent prior information (I-I minus I-C trials). These results imply the audiovisual congruency effects characterized by temporal synchrony may be modulated by individual characteristics related to the influence of prior information. Supported by NRF-2016S1A5A2A0102376.

#122 The ventriloquist aftereffect in the cat

Stephen G. Gordon, Stephen G. Lomber

Pre-perceptual recalibration of auditory and visual space due to spatially disparate audiovisual stimuli is known as the ventriloquist effect. This effect can be reproduced in an experimental setting by presenting a subject with a short noise burst while

simultaneously flashing an LED from a different location. After such a presentation, the perceived location of the auditory stimulus is shifted onto the visual stimulus. A by-product of this illusion is an aftereffect in which localization of an auditory stimulus is skewed in the direction of the visual stimulus with which it was previously paired. The magnitude of this aftereffect is only a fraction of the original discrepancy, but can persist as long as there are no simultaneous colocalized audiovisual stimuli in the environment. To date this aftereffect has been shown behaviourally in humans and non-human primates, while the brain regions involved have been inferred from fMRI. Based on this work, the ventriloquist effect and subsequent aftereffect are thought to be modulated by a pre-perceptual multisensory region of cortex, although the current fMRI data are not in a high enough resolution to parse out specific regions in auditory cortex. To better understand what region(s) of the brain underlie this phenomenon, we seek to replicate this effect in the cat. The cat is an animal model with very good localization ability, with auditory cortical areas that are largely on the gyral surface of the brain, allowing for electrophysiological recording and manipulation by cortical cooling. We will induce the ventriloquist effect using a stream of spatially disparate but simultaneous LED blinks and noise bursts. Following induction, the aftereffect will be measured behaviourally using head movements toward an auditory stimulus presented in isolation. The results from this experiment will be discussed within the framework of multisensory integration and cross-species comparisons will be made.

#123 Chemosensory convergence in the brainstem: Retronasal odorants modulate responses of taste cells in the parabrachial nucleus of the pons

Olga D. Escanilla, Patricia M. Di Lorenzo

The mechanisms underlying sensory integration of taste and odor stimuli that contribute to flavor perception are not well understood. In the brainstem, we found that taste and odor signals converge in the nucleus of the solitary tract (NTS; the first central nuclei relay in the gustatory pathway) of awake behaving rats (Escanilla et al., 2015). In addition, orthonasal odorants can modulate the responses of taste-responsive cells in the NTS. Here, we studied whether retronasal odorants would have the same modulatory effect on the taste responses observed in the parabrachial nucleus of the pons (PbN; the second central nuclei relay in the gustatory pathway) of awake-freely licking rats. To do this, rats were implanted an 8-tungsten wire electrode in PbN and allowed to recover.

Following moderate water deprivation, rats were placed in an experimental chamber containing a lick spout with access to presentations of various fluids. These consisted of taste only (0.1 M Sucrose, 0.1 M NaCl, 0.01 M Citric Acid, 0.0001 M Quinine, artificial saliva (AS)), retronasal odor only (0.01% octanoic acid or 0.01% phenylethyl alcohol, mixed in AS), and paired taste-odor stimuli (each odorant diluted in each tastant). Odor concentrations were below the detectable gustatory or somatosensory range in rats. Each taste, odor, or taste-odor stimulus was presented for 5 consecutive licks separated by 5 AS rinses on a variable ratio 5 schedule. Similar to the NTS, we found that cells in the PbN responded to tastants, odorants and taste-odor pairs. In addition, our results show that odorants alone, presented retronasally can also modify taste responses in the PbN. These preliminary results support the concept that the neural representation of flavor extends to the brainstem and possibly modulates downstream activities such as licking. Supported by NIDCD grant RO1DC006914 to PMD.

#124 Temporal and identity prediction in visual-auditory events: Electrophysiological evidence from stimulus omissions

Thijs van Laarhoven, Jeroen J Stekelenburg, Jean Vroomen

Abstract: A rare omission of a sound that is predictable by anticipatory visual information induces an early negative omission response (oN1) in the EEG during the period of silence where the sound was expected. It was previously suggested that the oN1 was primarily driven by the identity of the anticipated sound. Here, we examined the role of temporal prediction in conjunction with identity prediction of the anticipated sound in the evocation of the auditory oN1. With incongruent audiovisual stimuli (a video of a handclap that is consistently combined with the sound of a car horn) we demonstrate in Experiment 1 that a natural match in identity between the visual and auditory stimulus is not required for inducing the oN1, and that the perceptual system can adapt predictions to unnatural stimulus events. In Experiment 2 we varied either the auditory onset (relative to the visual onset) or the identity of the sound across trials in order to hamper temporal and identity predictions. Relative to the natural stimulus with correct auditory timing and matching audiovisual identity, the oN1 was abolished when either the timing or the identity of the sound could not be predicted reliably from the video. Our study demonstrates the flexibility of the perceptual system in predictive processing (Experiment

1) and also shows that precise predictions of timing and content are both essential elements for inducing an oN1 (Experiment 2).

#125 Tossing out vision: Modulation of audio-visual integration during rapid actions

Tristan Loria, Rachel Goodman, Luc Tremblay

Engaging in rapid upper-limb movements can modulate the integration of auditory and visual cues. For example, when moving the upper-limb towards a visual target, humans become less susceptible to an audiovisual illusion (Tremblay & Nguyen, 2010). Further, endpoint variability has been shown to be suboptimal following the provision of audiovisual feedback (e.g., Loria et al., 2016). A potential explanation for the modulation of audio-visual processing during rapid movements is the up-regulation of task-relevant feedback (e.g., vision when aiming to a visual target). The current study employed an auditory target to further probe the influence of target modality on sensory processing and integration. Participants (N = 13) performed a tossing movement requiring that the limb intersected a target at peak velocity (PV), which is akin to throwing skills. At PV, participants were also presented with either two asynchronous auditory, visual, or audiovisual cues from either side of the target. Participants judged which side the first sensory cue was presented (i.e., a temporal order judgment [TOJ] task). Participants also completed the TOJ task at rest. If sensory information congruent with the target modality is up-regulated during action, limb position variability at PV and TOJ accuracy should be better with the audiovisual and auditory cues, relative to the visual cues. The results showed that position variability at PV did not differ between sensory conditions while variability with audiovisual cues was greater than theoretically predicted values (e.g., Ernst and Bülthoff, 2004). For the TOJ task, accuracy did not differ across the sensory conditions at rest but, during the tossing task, participants were more accurate in the auditory relative to the visual and audiovisual conditions. Overall, sensory cues congruent with the target modality appear to be upregulated during action and such up-regulation may not occur in an optimal fashion. Acknowledgements: Natural Sciences and Engineering Research Council of Canada (NSERC), Canada Foundation for Innovation (CFI), Ontario Research Fund (ORF), and University of Toronto Graduate Student Bursaries.

Poster Abstracts

#126 Crossmodal attention alters contrast sensitivity for amplitude and frequency modulated auditory information via a mechanism of contrast gain

Vivian M. Ciaramitaro, Hiu Mei Chow, Luke G. Eglington

Attention has been shown to increase visual contrast and alter the visual contrast response function via contrast gain, as found for sustained visual attention, or via a combination of contrast and response gain, as found for transient visual attention (e.g., Ling & Carrasco, 2005). To investigate if similar mechanisms of attention are present in the auditory domain we used a two-interval-forced-choice dual-task paradigm to examine how covert, sustained, crossmodal attention altered auditory contrast sensitivity. Participants listened to two sequential intervals of sounds, one of which contained a white noise modulated in amplitude (Expt1: AM) or a 1000Hz pure tone modulated in frequency (Expt2: FM), and the other contained an unmodulated sound. Participants reported which interval contained the modulated sound. In the same intervals, a RSVP stream of 5 letters was presented at central fixation. In separate blocks of trials, participants judged which interval contained white letters (easy visual task) or, which interval contained a greater number of the target letter 'A' (difficult visual task). We examined how auditory contrast sensitivity varied as a function of visual task difficulty by fitting our data with a Weibull function and quantifying changes in auditory thresholds, asymptotes and slopes.We found greater thresholds, a greater modulation in the auditory stimulus required to achieve the same level of performance (75% correct) for both AM and FM sounds, for the more difficult compared to less difficult visual task. Auditory asymptotes and slopes did not differ with visual task difficulty. Changes in auditory thresholds with more or less crossmodal attention were best described by a change in contrast gain (shift), rather than a change in response gain (asymptote). Our results suggest that redirecting attention to a different modality, cross-modal attention, can influence auditory sensitivity via contrast gain, highlighting similarities between basic mechanisms for visual and auditory attention.

#127 Behavioural oscillations of perceptual sensitivity and criterion in vision and audition

David Alais, Hao Tam Ho, Johahn Leung, David C. Burr, Maria Concetta Morrone

Decades of psychophysiology have shown that neural activity is intrinsically oscillatory and various frequency bands are linked with functional specialisations. Using behavioural measures, recent work has shown that attention and perception for visual tasks also oscillate over time. Here, we study behavioural oscillations in vision (orientation identification) and audition (pitch identification) and show that sensitivity in both modalities oscillates over time. We sampled performance each 5 ms in a 800-ms window using either a voluntary action to reset the oscillation phase at the start of each trial (vision) or a noise burst (audition). For the first time in this field, we applied a signal detection approach to test separately for oscillations in sensitivity (d') and criterion (c). We fitted first-order Fourier series to the sensitivity and criterion data over time to look for standing oscillations, using permutation tests to assess significance. We found that d' and c both showed significant oscillations, in both modalities, and that they oscillate at different frequencies. In vision, d' and c exhibited alpha-band oscillations: d' = 8.5 Hz; c = 10.4 Hz. In audition, d' and c exhibited high-theta/low-alpha oscillations: d' = 6.1 Hz; c = ~8 Hz. Sensitivity in the left and right ears oscillated at the same frequency (6.1 Hz), but in opposite phase. These results suggest that oscillations are pervasive in both vision and audition, and that they affect sensory sensitivity as well as decision-level factors. The different frequencies for d' and c, for vision and audition, suggest distinct underlying mechanisms in each case, the anti-phase relationship between left and right ears (at the same frequency) suggests a possible phase-based code signals ear of origin.

#128 Multisensory spatial displacement of a visual illusory flash by auditory cues

Carmel A. Levitan, Bolton Bailey, Noelle R.B. Stiles, Armand R. Tanguay, Jr., Shinsuke Shimojo

The double flash illusion is a well known psychophysical phenomenon in which a pair of brief auditory tones (“beeps”), one slightly preceding and one following a single flashed stimulus, generate the perception of two separate flashes (Shams, et al., 2000). In a new variant of this phenomenon, the “spatial double flash illusion”, we observe that the two reported flashes are also perceived to be separated in space when the beeps are spatially separated. The visual stimulus was a white rectangle presented for 17ms against a grey background, located on the midline of a computer monitor and displaced 11.5Â° vertically below a central fixation cross in order to engage peripheral vision. The auditory stimuli were two 7 ms duration 800 Hz auditory tones separated by a 57 ms

delay. The speakers were separated by approximately 72.5 cm, one displaced to the left and one displaced to the right with respect to the center of the montor. In a series of trials, the auditory tones were either presented first on the left and then on the right, or first on the right and then on the left. In each trial, participants (N = 10) reported the number of flashes perceived. If two (or more) flashes were reported, participants then indicated whether or not the two flashes were collocated or displaced, and if displaced, the perceived direction of displacement. Participants reported displacement on more than 40% of the trials; this displacement was perceived to be in the direction of the auditory beep sequence significantly more often than in the opposite direction (left-to-right, $p = 0.011$; right-to-left, $p = 0.036$). Thus, we show that auditory information can influence spatial localization, an aspect of perception that vision is often thought to dominate, by inducing not only an illusory flash, but also its perceived displacement.

#129 Behavioral evidence for shared representations of peripersonal space between self and others

Wataru Teramoto

Space surrounding a body part, known as the peripersonal space, is an important space in the interaction of human beings with objects in their environment. Recent physiological and neuroimaging studies have shown that certain brain regions (or neurons) that respond to visual stimuli presented in the peripersonal space of self, also respond to those presented in the peripersonal space of others. This suggests that brain representations of peripersonal space can be shared between oneself and another person. However, since there is no behavioral evidence for this phenomenon, the present study investigated the concept of shared representation of peripersonal space. A white disc was projected from above on a table where a participant's hand was placed, and was moved toward or away from the hand in the near or far space of the participant's hand. While the disc was moving, a target (a vibrotactile stimulation on the tip of the index finger, a color change of the moving circle, or both) was presented. The participant's task was to detect the target(s) quickly. In the condition where the participant performed the task alone, the moving disc in the near space hastened the target detection especially when it was approaching the hand. In contrast, in the condition where the task was performed with a partner, who was facing the participant across the table, the target detection was hastened not only when the approaching disc

was presented in the near space, but also when the receding disc was presented in the far space (i.e., in the partner's near space). These results suggest that the human brain maps another's peripersonal space as if it were its own.

#130 Effects of developmental alcohol exposure on neuronal plasticity and multisensory integration in the cortex

Shiyu Tang, Rao Gullapali, Alexandre E. Medina†

† presenting author

Children with Fetal Alcohol Spectrum Disorders (FASD) often present sensory alterations such as aversion to multiple sensory stimuli presented at the same time, tactile hypersensitivity and poor visual sensory processing. There is growing evidence that disruption of Multisensory Integration (MSI) underlies these problems. MSI relies on the precise wiring of primary sensory systems and the accuracy of convergence of these systems to multisensory processing areas. This precision is acquired through neuronal plasticity processes that include sprouting and pruning of connections. Our group and others have shown that alcohol exposure during the third trimester equivalent of human gestation leads to a permanent disruption of cortical neuronal plasticity. Therefore, we hypothesized that developmental alcohol exposure disrupts the functional connectivity of multisensory cortical areas and impairs MSI. Based on this hypothesis, we used a ferret model of FASD to test the following predictions: 1-Alcohol exposed ferrets will display aberrant connectivity in the rostral posterior parietal cortex (PPr), a visual-tactile cortical area. 2-The PPr of alcohol exposed ferrets will display aberrant MSI.The degree of connectivity of PPr with its major visual (posterior parietal cortex, PPC) and tactile (third somatosensory cortex, S3) inputs was investigated by resting state functional MRI. Ferrets (n=9 per group) were exposed to 3.5 g/Kg of ethanol (BAL=~250mg/dl) or control saline between postnatal day (P) 10-30, a period that is roughly similar to the third trimester of human gestation. Between P45-P60 animals were scanned in a 7 tesla magnet. Z-scores indicated a higher correlation of the BOLD response between PPr-S3 and PPr-PPC in alcohol animals than in controls. These findings suggest that developmental alcohol exposure leads to hyperconnectivity in ferret PPr.To test if developmental alcohol exposure affects MSI, we conducted in vivo electrophysiology. Single units were recorded with a 16 channel electrode after visual only, tactile only or

visual+tactile stimulation. A total of 46 cells from two control animals and 103 cells from four ethanol treated ferrets were recorded. As expected, in the control group 37% of cells showed crossmodal depression, 24% crossmodal facilitation and 39% did not show MSI. This distribution is similar to what is described in the literature for normal ferrets. Strikingly, in the alcohol group, 82% of cells showed crossmodal depression, 8% crossmodal facilitation and 11% did not show MSI.Taken together, these findings suggest that developmental alcohol exposure lead to hyperconnectivity of multisensory processing areas and disrupt MSI. Further investigation of the mechanisms underlying these abnormalities will shed light on the causes of multisensory processing deficits seen in FASD.Supported by the NIH/NIAAA grants R01-AA013023 and R01-AA022455 to AEM.

#131 The race may be over: Behavior and neurophysiology show modality “switch-costs” give rise to apparent redundant target effect

Luke Shaw, Eric Nicholas, Matthew Braiman, Kamy Wakim, Ciara Molloy, Sophie Molholm, John Foxe

The facilitation of reaction times (RT) to a multisensory stimulus is a widely reported phenomenon in the field of multisensory integration. We show that a switch cost in RTs arises on the successive presentation of orthogonal unisensory stimuli. This switch cost accounts for much of the apparent RT facilitation to multisensory stimuli, which greatly impacts the interpretation of findings from standard redundant target effect paradigms. Neurotypical adult (n=30) participants performed a simple reaction time task to randomly interleaved audio and/or visual stimuli presented in a block-wise manner. Mixed stimulus blocks of this type were intermixed with blocks of purely audio, visual, or audiovisual stimuli for comparison. Behavioral data indicates increased RT latencies to unisensory stimuli immediately preceded by stimuli from the orthogonal modality. This effect is greatly reduced when unisensory stimuli are preceded by the multisensory stimulus or a stimulus of the same modality. RTs to the multisensory stimulus are not affected by this precedent effect, resulting in a comparative speeding of responses to multisensory stimuli. A complementary electrophysiological study (n=15) shows differences in evoked response potentials (ERPs) in line with behavioral findings. While differences are apparent, there is evidence for the consistent preservation of early

multisensory processing despite stimulus order upon presentation of the multisensory stimulus.

#132 Stimulus probability modulates visually induced auditory expectations whereas task requirements have only minor impact

Maria Viktoria Stuckenberg, Andreas Widmann, Erich Schröger

The human auditory system establishes sensory representations of expected auditory events based on predictive visual information. The amplitude of the N1 auditory evoked potential, observed around 100 ms after sound onset, has been shown to be enhanced in response to unexpected compared to expected sounds. This amplitude difference was interpreted as enhanced prediction error signal for unexpected sounds in the predictive coding framework and termed Incongruency Response (IR). Here we examined the impact of sound probability and task requirements on the elicitation of the IR. Each sound of either high or low pitch was preceded (stimulus-asynchrony 600 ms) by a note symbol either presented above or below a fixation cross. In 90% of the trials the visual symbol correctly predicted the pitch of the upcoming sound (congruent sound), whereas in 10% of the trials the sound was predicted incorrectly (incongruent sound). High and low pitch sounds were presented with equal (50% each) probability in one condition and with different probabilities (83.3 vs. 16.7%) in another condition (balanced across subjects). Subjects had to discriminate high vs. low pitch sounds in half of the blocks and congruent vs. incongruent sounds in the other half. Results reveal that the task had only minor impact on the IR. Importantly, a significant IR for unexpected (rare visual cue before frequent tone) compared to expected (frequent visual cue before frequent tone) sounds was confined to the condition with unequal stimulus probabilities. This suggests that it is easier to induce an auditory expectation by a visual cue when an established auditory representation can be re-activated. In contrast to this finding, previous investigations showed that the auditory system can establish sensory representations of expected auditory events based on a preceding sequence of scorelike visual symbols (with equal stimulus probability). Therefore, we assume that different mechanisms are active in single-trial tasks compared to enriched context tasks.

#133 Face discrimination in deaf and hearing individuals

Elizabeth Groesbeck, O. Scott Gwinn, Fang Jiang†

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Deaf individuals may possess enhanced visual processing abilities, particularly in the peripheries. Deaf individuals may also be more accurate at discriminating between faces, compared to their hearing counterparts. We examined deaf and hearing subjects' ability to discriminate faces using behavioral measures and EEG. In a delayed matching task, subjects were presented with a 'target' face and after a delay were required to identify which of two 'test' faces matched the target. A staircase was used to adjust the similarity between test images. In separate conditions, images were presented centrally and in the peripheries. Thresholds were calculated using Weibull functions to identify the level of similarity between test images associated with 79.4% correct performance. Overall deaf subjects were more accurate than hearing subjects and this difference was most evident in the peripheries. Neurophysiological responses to these images were then assessed using EEG and an oddball paradigm. In this paradigm face images are presented at a base frequency (6 Hz) and within the sequence a different 'oddball' face is presented at a lower frequency (1.2 Hz). The presence of a significant response at the oddball frequency would indicate the difference between faces has been detected. Compared to hearing subjects, deaf subjects showed a larger decrease in amplitude at the oddball frequency when images were presented in the peripheries compared to centrally. Deaf subjects also showed a larger decrease in amplitude when the similarity between the oddball image and base images was increased. We replicate earlier findings that deaf individuals may possess enhanced face processing abilities and further extend them by showing that these effects may be more prominent in the periphery. Furthermore, our results suggest that the enhanced processing ability in deaf for peripherally presented faces is not necessarily related to higher levels of neurophysiological responses.

#134 Monitoring of prediction errors facilitates cognition in action

John Plass, Simon Choi, Satoru Suzuki, Marcia Grabowecky

Cognition in action requires strategic allocation of attention between internal processes and the immediate sensory environment. We hypothesized that this balancing might be facilitated by mechanisms that predict sensory results of self-generated actions. Sensory signals confirming the predictions would be ignored to facilitate focus on internally generated content, whereas those violating the predictions would draw attention for scrutiny. In two visual working memory (2-back and digit span) experiments, we varied the temporal relationship between voluntary keypresses and auditory distractors so that the distractors were either temporally correlated or uncorrelated with keypresses. Consistent with our hypothesis, distractors were more likely to interfere with target maintenance and intrude into working memory when they were temporally uncorrelated with keypresses. Interference was maximal when sounds preceded keypresses, suggesting that distractor attenuation depended on inferred causality between keypresses and sounds. These results suggest that cognition during action is facilitated by monitoring prediction errors of sensory signals relative to expected action-perception contingencies. Because other statistical regularities in sensory input may also generate perceptual expectations, monitoring prediction errors across the senses may play a critical role in directing exogenous attention in general.

#135 Effect of speaker familiarity on perception of the McGurk effect

J.L. Mays, L.L. Zhu, J.F. Magnotti, M.S. Beauchamp

The McGurk effect depends on the integration of auditory and visual speech information despite their incongruence. Subjects might be less likely to integrate if the incongruence was more obvious, for instance if subjects were familiar with the particular speech mannerisms of the talker. To test this idea, we trained subjects using congruent stimuli from one talker (making this talker's mannerisms more familiar) and then tested McGurk perception using both the familiar talker and an unfamiliar talker, never before seen by the subject.Sixty subjects, recruited via Amazon Mechanical Turk, were split into two equal groups. Groups were trained on ten repetitions of 3 different congruent stimuli (AbaVba, AgaVga, AdaVda) from one of two different talkers (M1 or M2). After familiarization, the groups were tested on ten repetitions of a single McGurk stimulus

from the familiar and unfamiliar talkers, as well as 2 repetitions each of 3 congruent stimuli from a third talker. We chose M1 and M2 because in a previous study they elicited high average McGurk perception (77%, Basu Mallick, Magnotti, & Beauchamp, 2015) and we wanted to avoid the possibility of a floor effect obscuring any effect of familiarity.Across groups, McGurk perception was similar for familiar vs. unfamiliar talkers (mean McGurk familiar = 66.5%, SD = 40.4% vs. unfamiliar: 68.9%, SD = 38.2%). A linear mixed effects analysis on McGurk percept with familiarity as a fixed effect and subject nested in training stimulus as random effects yielded no substantial effect of familiarity [estimated effect = 2.3% SE = 3.1% p-value?]. We also found no difference in the distribution of McGurk percepts across subjects for familiar vs. unfamiliar stimuli, collapsing across training stimulus [Komolgorov-Smirnov test, D=0.083, p = 0.99]. Our results suggest that the integration of auditory and visual speech features that leads the McGurk effect occurs early, before speaker identification. Our results are consistent with previous findings that other talker-specific characteristics such as talker gender do not show a large influence on perception of the McGurk effect.

#136 Components of cross-sensory oscillations in the human brain

Shlomit Beker, Luke Shaw, Tufikameni Brima, John J. Foxe, Sophie Molholm

Information in the sensory environment tends to be highly predictive of upcoming events, allowing for online planning and decision-making. The neural processing of predictable stimuli is significantly facilitated compared to that of non-predictable stimuli. Thus, for example, temporally predictive visual information modulates the processing of incoming auditory information. The rhythmic patterns of stimulation coordinated across sensory modalities, such as audiovisual speech or the playing of a violin, are common in the environment and present a highly predictive state. To test the role of entrainment in cross sensory facilitation, we presented visual and auditory stimuli in which rhythmicity of temporally predictive events was manipulated, and measured cortical activity with high-density EEG from 16 human adults. We show that cortical entrainment, inferred by a cortical response to stimulus in different rhythms, is dependent on the degree of expectancy of the cross-sensory stimuli. This approach to understanding mechanisms underlying cross-sensory prediction provides a powerful tool to interrogate efficiency of brain anticipation for incoming stimuli.

#137 Bisensory association between sound and shape

Yuna Kwak, Hyun-Woong Kim, Ho-Sung Nam, Chai-Youn Kim

One of the compelling pieces of evidence for non-arbitrary audiovisual association is the Bouba-Kiki effect: people tend to label a round shape 'bouba' and a spiky shape 'kiki' (KoÌˆhler, 1947; Ramachandran & Hubbard, 2001). Previous studies, however, have not successfully disentangled phonetic features from other factors that might contribute to this association, such as linguistic and orthographical factors (D'Onofrio, 2014; Fort et al., 2015). To closely examine the influence of phonetic features, we used Haskins Articulatory Synthesizer to generate auditory stimuli that are not confined to any language or orthographic system. Twenty-five vowel sounds were created by equi-distantly manipulating the height and frontness of the tongue body position, and 12 consonant sounds were generated by parametrically manipulating the oral (lips, tongue tip, tongue body) and non-oral (glottis, velum) constriction gestures, with the vowel gesture fixed at its rest position. Multidimensional scaling analysis of the synthesized sounds confirmed that physical spaces conformed to perceptual space, showing the effectiveness of the manipulation of the physical parameters. Experiment 1: 40 participants listened to the vowel sounds and were asked to choose between round and spiky shapes. Results showed the main effects of height and frontness ($p = .001$): high and front vowels (e.g., /i/) were associated with spiky shape, and low and back vowels (e.g., /a/) were linked with round shape. Experiment 2: 40 new participants listened to consonant sounds, with which they had to associate either round or spiky shape. Results showed that sounds generated with the lip organ (e.g., /be/, /me/) were associated with round shape whereas consonants with glottal gestures (e.g., /keh/, /kheh/) were associated with spiky shape, both significantly above chance ($p = .001$). These results indicate that phonetic, not other features indeed play a vital role in the Bouba-Kiki effect, exemplifying a non-arbitrary relationship between sound and shape. Supported by NRF-2016R1A2B4011267.

#138 Causal inference in the perception of verticality

Ksander N. de Winkel, Heinrich H. Bülthoff

It has been proposed that the perception of 'up' is constructed by the brain as a vector sum; combining estimates of the visual vertical, the orientation of gravity, and the prior

knowledge that 'up' is usually above our heads - called the idiotropic vector (Mittelstaedt, 1983). In a more recent study (Dyde et al., 2006), the weighting of the respective cues was found to be consistent with predictions from Bayesian accounts of perception. However, a study conducted in partial gravity (De Winkel et al., 2012) has shown that visual cues were discarded entirely, and that the contributions of the idiotropic vector and gravitational vertical have a dichotomous nature under conditions of reduced gravity. These findings suggest that the analogy of a vector sum does not always apply. Here we investigate how the perception of vertical is affected by intersensory discrepancies. We presented our participants with an array of visual and inertial orientation stimuli using a motion platform and a newly developed augmented reality system, and tasked them to indicate the perceived vertical. We will discuss the study's findings, and their implications for theories on orientation perception.

#139 Visuo-proprioceptive realignment in hand perception associated with modality-specific changes in motor corticospinal excitability

Hannah J. Block, Jasmine L. Mirdamadi, Anna K. Lynch

Hand position can be estimated visually, from an image on the retina, and proprioceptively, from sensors in the joints, muscles, and skin. The brain is thought to weight and combine available sensory estimates to form an integrated multisensory estimate. Inherent in this process is the capacity to realign one or both sensory estimates when they become spatially mismatched, as when washing dishes with the hands immersed in water, which refracts light. Sensory realignment affects perceived hand position, which the brain must use to plan hand movements. Multisensory perception and motor control are thus linked functionally, but the physiological substrates of this connection are not well understood. Here we experimentally imposed a mismatch between visual and proprioceptive estimates of index finger position and measured motor corticospinal excitability. 32 healthy adults completed two sessions each, experiencing spatially misaligned or veridical visual and proprioceptive information about their static index finger. Subjects received no performance feedback or knowledge of results. Transcranial magnetic stimulation (TMS) was used to assess primary motor cortex (M1) representation of an index finger muscle. In the misaligned session only, perceptual realignment predicted changes in M1 excitability. Indeed, results were modality-specific, with proprioceptive realignment associated with a decrease, and visual

realignment with an increase, in excitability. We also investigated whether these associations were mediated through sensorimotor networks by measuring short latency afferent inhibition (SAI) in a subset of subjects. On average, SAI was reduced in the misaligned session compared to the veridical session, suggesting decreased inhibitory activity in connections between somatosensory and motor cortices. This effect was most apparent among subjects who relied more heavily on vision than proprioception. Taken together, our results suggest that spatial realignment in multisensory perception is associated with modality-specific changes in M1, perhaps mediated by altered somatosensory projections to M1.

#140 Startling sounds presented under dark adaptation evoke synesthetic experiences in non-synesthetes

Anupama Nair, David Brang

Synesthesia is a perceptual phenomenon in which stimulation of one sensory modality evokes additional experiences in an unrelated modality (e.g., sounds evoking colors), thought to arise from increased connectivity between associated sensory areas. However, non-synesthetes can experience these sensations via hallucinogenics or due to brain damage, suggesting that synesthesia may exist as a latent feature in all individuals, manifesting only under certain contexts. Indeed, multisensory connections exist in all individuals that facilitate dynamic sensory processing, but inhibition of sensory pathways and dominant bottom-up information may prevent normal multisensory interactions from evoking synesthetic experiences. In this study, we sought to counter these two features of normal sensory perception in order to evoke auditory-visual synesthetic experiences in non-synesthetes. Participants completed an auditorily-presented visual-imagery task to increase top-down feedback to early visual areas while in a visually deprived environment. During this state, subjects were presented with sounds from either of two spatial locations at random and infrequent intervals. Across three experiments, in which the types of sounds were varied, we evoked auditory-driven visual hallucinations in approximately 60% of non-synesthetic individuals. Visual hallucinations were time-locked to the onset of the sounds and produced vivid visual experiences including colors and basic textures/shapes, akin to KlÃ¼ver's form-constants. Behavioral responses and subject debriefings confirmed that the visual hallucinations were most often triggered by mildly startling sounds (70 dB, 10kHz) relative to non-startling sounds, and were either

spatially coincident with the location of the sound or experienced as a full-field flash of light. Ongoing work is using EEG to understand the neural mechanisms of this phenomenon and its relation to other multisensory processes (e.g., the auditory-evoked contralateral occipital positivity). These results indicate a higher prevalence of synesthetic experiences in the general population in specific contexts, and provide a potential link to normal multisensory processes.

#141 The crucial (yet easily overlooked) role of amplitude envelope in audio-visual integration

Michael Schutz

The perceptual system continually integrates across sensory modalities. Although this phenomenon has been well studied, my presentation will discuss new data highlighting challenges with generalizing from findings based on artificial sounds.The ventriloquist effect clearly illustrates the ability of one modality to influence another. Psychophysical explorations using tone beeps and light flashes led to the theory of “optimal integration” (Ernst & Banks, 2002; Alais & Burr, 2004)- powerful formal language explaining outcomes from many experiments. However this approach does not take into account the causal relationship between sights and sounds- the degree to which they “go together.” For example, faces and voices integrate more strongly when gender matched vs. mismatched, as they trigger the “unity assumption” - recognition they derive from a common source (Vatakis & Spence, 2007). Although subsequent studies found the unity assumption did not apply to musical sounds (Vatakis & Spence 2008), recent work from my team illustrates this is possible - for instruments with clearly differentiable amplitude envelopes (Chuen & Schutz, 2016). These results extend previous demonstrations of amplitude envelope's crucial importance (Schutz, 2009; Vallet, Shore, & Schutz, 2014). However, amplitude envelope's role often goes unnoticed. A survey of stimuli used in the journal Music Perception found it is not even reported for 35% of stimuli (Schutz & Vaisberg, 2014). To formally explore the sounds used in auditory perception research, my team has reviewed of hundreds papers totaling 1000 experiments selected from four prominent journals: Attention, Perception & Psychophysics and Journal of Experimental Psychology: Human Perception and Performance, and the Journal of the Acoustical Society of America. This large scale, randomized survey is the first full scale documentation of the heavy reliance on amplitude invariant sounds. My presentation will

discuss how this disproportionate focus has encouraged research that might not generalize to our everyday perceptual experiences.

#142 A new approach to develop haptic feedback based on multisensory integration

EunHee Chang, Chan Hyun Park, Hyun Taek Kim

Many previous haptic technologies have focused on developing methods to simulate human tactile sensations, which requires complex and delicate devices. In this study, we suggest a novel approach for inducing haptic feedback based on multisensory integration. We tested whether the multisensory information would induce haptic sensations through the use of a rough textured virtual object. Thirty-one participants (18 elders and 13 undergraduate students) experienced three different multisensory conditions: congruent, incongruent, and control. In the congruent condition, participants heard a rough-textured sound as they touched the rough virtual object. Participants in the incongruent condition heard a smooth-textured sound instead of a rough- textured sound. For the control condition, they touched the rough virtual object without a sound. After each condition, participants answered a roughness sensation questionnaire (RSQ). A repeated-measures ANOVA was conducted on RSQ scores with conditions (congruent vs. incongruent vs. control) as a within-subject factor and groups (elders vs. undergraduate students) as a between-subject factor. The result showed that there was a significant main effect of condition ($F = 18.420$, $p = .001$). In other words, participants experienced a rough feeling only in the congruent condition regardless of age. This result shows a new possibility of developing haptic feedback of texture using congruent multisensory information, which can be an alternative to complicated haptic technologies.

#143 Background motion caused by self-motion does not cause motion-induced blindness

Yasmeenah Elzein, Laurence R. Harris

The phenomenon of motion-induced blindness (MIB) is when salient targets tend to disappear when superimposed on a moving background. However, studies on MIB have been restricted to using small-field background motion. In realistic scenarios, full-field

background motion is typically associated with self-motion in contrast to small-field background motion which is typically attributed to external motion. Visual motion resulting from self-motion is normally invisible; does it cause MIB? Participants sat in the York University Tumbling Room, a room that can rotate around the naso-occipital axis and in which the chair can also rotate around the same axis. Salient targets 2.8Â° from a fixation point were provided by three lasers attached to the chair. Participants viewed the display in full-field or in small-field-of-view (FOV Â± 5Â°) created by wearing masked-down goggles. Participants fixated a central point during rotations of the room or the chair at 3rpm for 120s with or without the goggles and pressed a button when any of the targets disappeared. Results were compared to a no-movement condition as fixation can also cause targets to disappear (Troxler fading). Rotation of the tumbling room evoked vection 94% of the time during full-field viewing and 8% of the time with the goggles. MIB occurred when the participant was stationary viewing with a small-FOV. In all other cases, MIB beyond Troxler fading was not found. When participants attribute motion background as resulting from their own self-motion, regardless of whether the background motion is visually- or physically-caused, this seems to consume the background motion that generates MIB therefore attenuating the effect. This suggests that background motion caused by self-motion is removed from perceptual processing before the point at which MIB occurs.LRH was sponsored by a Discovery Grant from the Natural Sciences and Engineering Council (NSERC) of Canada. YE was an NSERC CREATE scholar.

#144 Investigating the developmental course of multisensory speech integration using a hierarchical EEG framework

Michael J. Crosse, Aida M. Davila, John J. Foxe, Sophie Molholm

Electrophysiological (EEG) investigations of audiovisual (AV) speech processing in children have typically used discrete AV speech stimuli such as monosyllabic nouns (e.g., Knowland et al., 2014). However, such stimuli may only partially engage the underlying cortical networks involved in the processing of natural AV speech. Furthermore, neural responses time-locked to such brief stimuli still reflect a myriad of hierarchical processes (e.g., acoustic, phonetic, lexical), making it difficult to isolate multisensory interactions at a specific stage of speech processing. System identification (SI) provides an analytical tool for decoding specific features of continuously-modulating stimuli from recorded

neural responses. SI techniques such as regularized linear regression have recently been used in adult EEG studies to obtain neural correlates of multisensory integration in response to natural AV speech (Crosse et al., 2015), and isolate neural indices of speech processing at discrete stages of the auditory cortical hierarchy (Di Liberto et al., 2015). Here, we consolidate these complimentary frameworks in order to track the developmental course of multisensory speech integration in a hierarchical manner. Specifically, we presented 180 Ã— 30-s movies of a speaker reciting children's stories to children (N = 8) and adults (N = 8) while recording high-density EEG. The stimuli alternated between audio-only, visual-only and audiovisual speech and were accompanied by acoustic noise at 3 different signal-to-noise-ratios (SNRs; 2 dB, âˆ’9 dB and âˆ’14 dB). Each of the speech stimuli were transformed into a spectrotemporal and phonetic representation, which were mapped to the multi-channel EEG recordings in both the forward and backward direction. The resulting “encoding” and “decoding” models were used to quantify how neural entrainment to low- and high-level auditory speech features is differentially affected by visual speech information as a function of SNR. This multifaceted approach offers a novel framework for studying the neurophysiology of multisensory speech processing throughout development.

#145 Lipreading primes auditory cortical networks prior to speech onset: evidence from invasive neural recordings in humans

EunSeon Ahn, Adrian Rakochi, L. Jacob Zweig, Satoru Suzuki, Marcia Grabowecky, Vernon L. Towle, James X Tao, Shasha Wu, William Stacey, David Brang

The presence of congruent visual lip movements with auditory speech improves speech perception in noisy environments, whereas incongruent lip movements (e.g., an auditory /BA/ and a visual /GA/) impair speech perception accuracy. Speech-related visual cues (including lip movements) typically begin prior to the onset of auditory speech signals, enabling visual information to bias auditory processes. Prior research using non-invasive electrophysiological techniques has demonstrated that phoneme information extracted from lip movements is relayed from the posterior superior temporal sulcus to the auditory cortex and facilitates the processing of the auditory phoneme. However, these measures lack sufficient spatial resolution for determining the precise areas of the brain in which the relevant electrical signals underlying these perceptual changes arise and they provide limited information on the neural mechanisms through which visual lip

movements modulate auditory speech perception. To better understand these mechanisms, we recorded electrcorticographic (ECoG) activity from electrodes implanted within the primary/secondary auditory cortices of 10 patients with epilepsy while they perceived auditory phonemes in isolation or paired with movies containing congruent or incongruent lip movements. In order to examine the influence of visual information on population-level spiking activity, we examined high gamma band activity (70-250 hz; HGA) in response to phonemes. Signals measured at the auditory sites during auditory-alone trials revealed robust increases in HGA relative to the pre-stimulus fixation baseline. Deviating from this auditory-alone condition, congruent auditory-visual trials showed significantly reduced HGA, whereas incongruent auditory-visual trials showed significantly increased HGA, with these effects significant at both the individual subject and group levels. These data are consistent with predictive coding models of perception, in which the visual lip movements prepare the auditory neurons in expectation of a specific oncoming phoneme, in order to facilitate perceptual processes. We are currently investigating specific physiological mechanisms through which visual information modulates auditory processing.

#146 Disembodied touch: A mirror-induced illusion

Jared Medina, Samuel D. Katz

We developed a novel version of the mirror box illusion to explore whether tactile sensation could be felt outside of one's body. The participant's hands were 6” apart, creating a spatial mismatch between the mirror reflection of the left arm and the actual, unseen right arm (as in Medina, Khurana & Coslett, 2015). In the large mirror condition (as in a typical mirror box experiment), participants could see the reflection of both their left hand and forearm. In contrast, in the small mirror condition, participants saw only the reflection of their left hand without the forearm. During bimanual synchronous tapping with the small mirror, this often created the illusion that the participant's own right hand was in the mirror without an attached forearm. We then presented tactile stimuli to their unseen right hand or distal forearm, and asked participants to report whether they felt touch on/near the mirror reflection of their hand, or at the actual location of their right arm. First, participants were equally likely to feel touch on the mirror reflection of the hand in both the large and small mirror conditions. Second, participants were significantly more likely to feel touch on the mirror reflection of the distal forearm in the

large versus small mirror condition, demonstrating that seeing the forearm increased the likelihood of feeling touch on that forearm. Interestingly, on approximately 20% of forearm stimulation trials with the small mirror, participants reported feeling touch in the empty space where the forearm would be expected. In a follow-up experiment, we found that on half of these trials, participants felt that the forearm was in its actual location, yet still experienced touch in empty space. We discuss how embodiment of the "detached" hand, combined with expectations derived from the body schema, leads to this illusory percept.

#147 Enhancing the effect of full-body vibration generated from audio signal on perceived reality

Zhenglie Cui, Hiroyuki Yagyu, Shuichi Sakamoto, Yôiti Suzuki, Jiro Gyoba†

† presenting author

With the recent advances in information technology, it is now possible to synthesize and present multisensory content comprising not only audio-visual (AV) information, but also information of other sensory modalities. To develop future multi-modal displays, it is imperative to present various kinds of sensory information with proper intensities and timing. To that end, we investigated the effect of full-body vibration on the perceived reality of multisensory content at the point of spatio-temporal interaction. Previously, we reported that full-body vibration, when presented at proper amplitude and timing, can enhance the perceived reality of multimodal content. However, almost all multimedia content easily available only include AV information. Therefore, we conjecture that effective vibration information obtained from other sensory information may prove useful, especially from sound information. In this study, we attempt to generate such vibration information from low frequency components (= 70 Hz) of the audio signal of AV content. We recorded AV content from a basketball game. Visual information was presented via DLP projector, and auditory information was presented binaurally via headphones. The variation in amplitude of the generated vibration was used as the input parameter. Using this information, we conducted psychophysical experiments to evaluate perceived reality in terms of the sense of presence and verisimilitudes. The experimental results revealed that the generated full body vibration enhances perceived reality of multi-modal contents during the presentation as well as after the replay. Moreover, it was

observed that the sense of verisimilitude sensitively depends on the intensity of the full-body vibration than the sense of presence. These results clearly indicate that low-frequency sound can be effectively used to enhance perceived reality. The results also suggest the importance of verisimilitude as another useful measure to evaluate the perceived reality in addition to the sense of presence.

#148 What makes a shape /baba/ to a child versus an adult? Changing contributions from shape contour, protrusion number, and protrusion size in sound-shape correspondence

Doris Chow, Vivian M. Ciaramitaro

Sound-shape correspondence is the association between abstract shapes and sounds. One example is the bouba/kiki effect, in which a round shape is associated with a sound like /bouba/ whereas a spikey shape is associated with a sound like /kiki/. Shape features like contour and the number and size of protrusions have been identified as relevant visual features (Chen et al., 2016). The weight assigned to a particular visual feature can vary based on the perceptual processing style an individual adopts (Chen et al., 2016). Given literature suggesting that children may adopt a different perceptual style than adults (e.g. Dukette & Stiles, 2001; Nayar et al., 2015; Poirel et al., 2008, 2011), we hypothesized that children might prioritize shape features differently from adults and tested this using the bouba/kiki effect. 91 participants (6-35 years old) judged which of two sounds best matched the shape presented at screen center. Across trials, the shape varied in contour (round or spikey), protrusion number (3 or 7 protrusions), and protrusion size (small or large protrusions). We quantified how often an /a/ sound (/baba/ or /gaga/) was chosen over an /i/ sound (/kiki/ or /titi/) for each shape. We found that adults associated /i/ sounds with shapes having spiky contours and 3 small protrusions. Of these shape features, shape contour showed the strongest association. While 9- year olds showed adult-like shape processing biases, 6-8 year-olds prioritized protrusion number, not shape contour. Yet, in a follow-up experiment highlighting shape contour by presenting round and spikey shapes side-by-side, 6-8 year-olds could make associations based on shape contour. Our findings suggest different features of a shape are prioritized when making sound- shape correspondence by 6-8 year-olds versus adults, but that shape processing biases can be altered by context such that children can resemble adults when the relevant shape features are highlighted.

#149 The effects of modality switching and maintaining on visual and auditory detection

Ying Fang, You Li, Nan Liu, Hui Li, Yizhou Jiang, Qi Chen

A previous trial influences the performance in the subsequent trial. Recent researches endeavor on how the conditions on the previous trial affect the performance of present trial in the same modality. Whether and how previous stimulus from different modalities modulates neural activity and behavioral performance in current trial remains unclear. In this study, we aim to investigate the neural mechanism underlying the influence of modality switching and maintaining on visual and auditory detection by using fMRI technique. Participants (n=20) performed the visual (a white sphere) and auditory (4,000Hz tone) detection task. Based on the combination between previous and present trials, we differentiated four conditions of interest, visual switching (AV) and maintaining (VV), auditory switching (VA) and maintaining (AA) trials. Behaviorally, RTs in the maintaining condition were faster than the switching condition in both visual and auditory modalities. Imaging results showed that when the modality switched, bilateral inferior parietal cortex and the supplementary motor area showed significantly enhanced neural activity compared with that when the modality maintained. In contrast, when the modality maintained, the right medial frontal gyrus and the right inferior frontal gyrus showed less deactivations compared with that when modality switched. More importantly, RTs in both visual and auditory maintaining were associated with increased pre-trial neural activity in bilateral superior parietal gyrus. Moreover, pre-trial activity in the default-mode network was positively correlated with the RTs in the visual switching (AV) trials, while pre-trial activity in the left middle occipital gyrus was negatively correlated with the RTs in the auditory switching (VA) trials. Taken together, the results of this study reveals both the neural consequences of cross-modal trial history and the neural causes of subsequent behavioral performance.

#150 The timing of multisensory enhancements in physiological response reliability

Alexander S. Dakos, Barry E. Stein, Benjamin A. Rowland

A well-known capability of superior colliculus (SC) neurons is their ability to integrate information from different sensory modalities and thereby enhance physiological responses and the behaviors that depend on them. These multisensory response enhancements are typically most prominent, and most frequently “superadditive", during

the initial phase of the multisensory response (the “Initial Response Enhancement", IRE, see Rowland et al., 2007). However, firing rate enhancements are only one way in which multisensory integration can enhance the salience of an initiating event. Theoretical principles predict that there should be an accompanying increase in response reliability, reflected by a decrease in themean-normalized trial-by-trial variability of theresponse. This possibility was examined by evaluating the magnitude and reliability of SC responses to a variety of visual and auditory stimuli presented alone and together in spatiotemporal concordance. The trial-by-trial variability of multisensory responses (but not unisensory responses) was consistently lower than expected given variation observed in spontaneous windows (P=.001), as well as significantly lower than the summed unisensory response variances (P==.001). The magnitude of this decrease in variation was largest within the IRE, when response enhancement is largest, and was well-predicted by a Bayesian model of stimulus detection. These findings indicate that multisensory neurons are not simply passive common conduits through which cross-modalsignals are relayed, or trivially boosted by an additive factor. Rather, the products of integration are determined by an efficient nonlinear transform that not only amplifies signals, but renders them more reliable. Furthermore, these enhancements are largest during the IRE, when multisensory responses are most likely to influence overt behavior. Supported by NIH grants 2T32NS073553 and EY016716 and the Tab Williams Family Foundation.

#151 Responses of prefrontal neurons during enhancement of auditory discrimination with face distractors in nonhuman primates

Lizabeth M. Romanski, Jaewon Hwang, Shraddha Shah, Bethany Plakke

It is well known that speech perception is enhanced by matching visual input. For example, Sumby and Pollack (1954) showed that faces improve speech intelligibility, especially when the auditory stimulus is degraded. It has also been shown that emotional evaluation of faces is enhanced with accompanying voices (deGelder and Vroomen, 2000). The enhanced perception or recognition that occurs when vocal stimuli are accompanied by faces was investigated in our laboratory in rhesus macaques. 2 monkeys were trained in an auditory discrimination task using species-specific vocalizations as the memoranda. When accuracy reached a criterion of 75%, matching face and non-face stimuli were presented with the vocalizations. The task included

conditions of vocalization-alone, face movie + vocalization, static face + vocalization, object movie + vocalization, fractal image + vocalization. Discrimination performance was assessed and compared across all stimulus conditions. It was found that the conditions where the vocalization stimulus was paired with a congruent face during the sample period resulted in enhanced accuracy compared to the condition where a vocalization was presented alone. Furthermore, conditions where the vocalization was paired with a non-face stimulus resulted in decreased accuracy compared to the face plus vocalization conditions. This confirms previous findings of enhanced performance with multisensory compared to unisensory information. However, the effect is even more striking given that the face stimulus was irrelevant in solving the task. Recordings from ventrolateral prefrontal cortex (VLPFC) neurons have previously shown multisensory responses to face and vocalization stimuli. Therefore, VLPFC recordings during this task were also undertaken to determine if prefrontal neurons demonstrated enhanced responses during face + vocalization conditions.

#152 Crossmodal learning mechanisms change from development to adulthood

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While adults adapt their acquired internal models of the sensory world, infants first need to learn the sensory properties of their environment. Here we used event-related potentials to test the hypothesis based on animal findings that the mechanisms of crossmodal learning differ in development and adulthood. We hypothesized that infants pick up crossmodal statistics by pure exposure while adults learn new crossmodal statistics only if they are task relevant. In the first experiment we tested a group of six-month-old infants and a group of young adults: two frequently occurring audio-visual standard combinations (A1V1, A2V2, p = 0.35 each), two rare recombinations of the standard stimuli (A1V2, A2V1, p = 0.10 each) and one rare audio-visual combination of a deviant auditory and a deviant visual stimulus (A3V3, p = 0.10) were passively presented. Event-related potential indicated that infants were able to discriminate both the standard and rare deviant stimuli (ERP latency: 200 ms) as well as the standard and rare recombined stimuli (ERP latency: 420 ms). In adults only the first effect was

observed (ERP latency: 180 ms). In a second experiment we tested an additional group of young adults in adapted versions of the same experiment: Participants had to detect a rare unimodal visual stimulus rendering crossmodal stimuli task irrelevant. ERPs revealed that the adult participants detected the rare deviant stimuli but that they did not differentiate between the standard and rare recombined stimuli. Adults discriminated the latter only when crossmodal combinations were made task relevant (ERP latency: 250 ms). These results demonstrate a high sensitivity for crossmodal statistics in infants. We speculate that initial passive association learning allows infants to quickly generate internal models of the sensory world. Adults adjust existing internal models based on experience by taking task context into account.

#201 Electrophysiological evidence for multisensory integration contribution to decision making

M.R. Mercier, C. Cappe

A large body of research on perceptual decision-making has shown that, during a visuo-motor task, the choice of an action relies on the gradual accumulation of evidences reaching a decisional bound. In multisensory context, different sensory channels provide complementary and/or redundant information, whose integration leads to behavioral benefit by reducing uncertainty within each sensory stream. However, the influence of multisensory integration processes on perceptual decision making mechanisms remain largely unknown. In the present study, we aimed at investigating this question using surface EEG in humans, while subjects had to detect, or to categorize, unpredictable auditory and/or visual targets embedded within a stream of audiovisual noise. Our approach was first directed at tracking the neuronal signatures of building up sensory evidences in response to unisensory signals, so as to be able, in a second step, to characterize the specifics of decision-making following multisensory cue. In agreement with previous literature, we found early markers of multisensory integration along the chain of processes leading to behavioral response. More interestingly, this multisensory effect found during sensory information encoding then appears to foster the dynamic of evidences accumulation. That is, our analyses show that accumulation of evidence is faster in the multisensory condition as compared to the unisensory conditions, by means of multisensory cue integration. These findings reveal that early combination of sensory

information participate in the operationalization of the decisional process by promoting the rate of sensory evidence accumulation.

#202 A high-level cognitive prosthesis for blind people

Yang Liu, Noelle Stiles, Markus Meister

Most prosthetic approaches to blindness focus on conveying raw visual images to the subject. Examples include electrode arrays implanted in the retina and auditory or haptic sensory substitution devices. The hope is that despite unavoidable corruptions of the image, the brain can still extract the precious bits of actionable information needed for "seeing" and acting. As an alternative we are building a prosthesis in which a computer compiles all the actionable information, and only those few bits are conveyed to the subject. The computer narrates the scene to the user in natural language: objects and their locations, faces and their identities, options for navigation. Our immediate goal is to enable blind people in their social interactions and indoor navigation in unfamiliar buildings. Secondly we hope that the narrative creates a rich mental image of the surroundings to convey a sense of seeing. The front end of this system, namely the high-level interpretation of the scene, is being solved with accelerating progress by computer vision researchers. We report on the back end, namely the auditory narration of that knowledge. Our prototype called "SceneReader" is built around a powerful augmented-reality computer, the Microsoft Hololens. The system assigns a voice to each relevant object in the environment. These objects speak to the user through head-worn speakers, with the sound appearing to come from the object's location. The user can choose among several modes of narration depending on the current task she wants to perform. One mode initiates a "virtual guide", an object that moves along a specified navigation route, staying two steps ahead of the user, with repeated calls of "follow me". We will show that a congenitally blind subject can navigate an unfamiliar corridor on the first attempt at a walking speed normal for sighted people.

#203 Sensing the world through a hand-held tool

Luke E. Miller, Luca Montroni, Romeo Salemme, Vincent Hayward, Alessandro Farnè

In the seventeenth century, Descartes famously discussed a blind man's ability to actively navigate his environment with a cane. Still, almost four centuries later, we have very limited knowledge of what environmental properties can be sensed with a tool (e.g., Yamamoto & Kitazawa, 2001) and how tools gate meaningful sensory information to the user (e.g., Emerson & Rodgers, 2005). By combining psychophysics and contact mechanics, we show that a tool communicates sensory representations of object impact location to the user's hand with previously unexpected accuracy. In three psychophysics experiments, we find that human participants can localize where an object contacts a hand-held rod with high spatial resolution. Given the structural dynamics of rods, we reasoned that this ability reflects perceptual mechanisms that are highly sensitive to location information encoded in the tool's natural modal response to impacts. By leveraging multivariate methods that are commonly used to characterize neural representations, we find that tools mechanically transduce object location into a vibratory codes upon impact. The structure of these vibratory input motifs are consistent across trials and emerge within ~20 ms. Thus, the vibratory response of a rod constitutes a meaningful pre- neuronal transformation that can be exploited by the nervous system during perception, a finding that has parallels in the rat whisking system (e.g., Bagdasarian, et al., 2013). We further find that location information is encoded in the higher frequencies of the modal response, suggesting that location information could be rapidly and precisely transduced into neural signals by afferents in the hand. In sum, our results demonstrate that a hand-held tool functions as an extended sensory apparatus, letting the user sense the location of objects beyond the boundaries their physical body. Our future work will investigate the contributions of other sensory modalities to tool-mediated sensing.

#204 Temporal processing of audio-visual speech as regulated by cortical oscillations in the alpha frequency range

James W. Dias, Carolyn M. McClaskey, Kelly C. Harris

Cortical oscillations in the alpha frequency range (8hz-14hz) have been associated with the temporal processing of sensory events. Specifically, as peak alpha frequency

increases, the temporal windows in which separate sensory events integrate to form unified percepts can narrow (Samaha & Postle, 2015; Cecere, Rees, & Romei, 2015). For example, two asynchronous events falling within a relatively wide temporal window cannot be segregated and generate a single integrated percept. However, when the same two events fall across two relatively narrow temporal windows, the events are segregated and generate two percepts. The relationship between alpha oscillations and the integration of sensory events, both within and across modalities, has previously been investigated using visible flashes and audible beeps. However, alpha may also affect the perception of more complex forms of information. Behavioral evidence from the speech domain suggests that incongruent auditory (voice) and visual (lipread) speech information can generate integrated percepts (e.g., McGurk & MacDonald, 1976) even when the auditory and visual signals occur asynchronously (e.g., Munhall, Gribble, Sacco, & Ward, 1996; van Wassenhove, Grant, & Poeppel, 2007). The temporal windows in which such crossmodal speech information integrates can vary substantially between individuals. Some of this variability may be accounted for by the oscillatory characteristics of individual perceivers, in the alpha frequency range. We present preliminary data investigating the relationship between peak alpha frequency and the integration of asynchronous audio-visual speech information. The results will be discussed with regards to the role peak alpha frequency may play in regulating the temporal windows in which speech information is segregated and integrated across sensory modalities.

#205 Peripherally-presented sounds facilitate early visual processing of spatially aligned visual targets: Evidence from intracranial electrophysiological recordings in humans

Adrian Rakochi, EunSeon Ahn, Anupama Nair, Vernon L. Towle, James X Tao, Shasha Wu, William Stacey, David Brang

Neurophysiological studies in animals suggest that sounds modulate activity in primary visual cortex in the presence of concurrent visual stimulation. Noninvasive neuroimaging studies in humans have similarly shown that sounds modulate activity in visual areas even in the absence of visual stimuli or visual task demands. However, the spatial and temporal limitations of these noninvasive methods prevent the determination of how rapidly sounds activate early visual cortex and the mechanisms that support this multisensory communication. Using spatially and temporally precise measures of local

synaptic activity acquired from intracranial electrodes in humans, we examined auditory-evoked visual activity in two paradigms. In Experiment 1, participants detected centrally presented 1 kHz tones and ignored peripherally presented noise bursts. Data demonstrate that peripherally presented sounds evoke activity in primary/secondary visual cortices in a spatiotopic manner within 30-50 ms of sound presentation. Critically the timing of this sound-evoked visual activity precedes that of normal visual responses to visual stimuli, suggesting that the prior-entry of spatiotopically organized auditory information into visual cortex primes visual neurons for oncoming visual stimuli. In Experiment 2 we tested this hypothesis by presenting peripheral noise bursts 400 ms before a visual target that was either spatially aligned or misaligned with the preceding auditory cue. We first replicated the results of Experiment 1, and second, we examined the influence of the sounds on visual target processing according to auditory-visual spatial alignment. Critically, population neuronal firing rates in early visual areas were significantly reduced to a visual target when preceded by a spatially aligned auditory cue (e.g., visual targets and auditory cues both presented in the right visual field), relative to spatially misaligned auditory cues. These data are consistent with predictive coding models of perception, in which auditory cues prepare visual neurons for oncoming visual stimuli in order to facilitate perceptual processes.

#206 Embodied geometry: The role of development on perceived angular magnitude across vision and haptics

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† presenting author

We perceive our environment through multiple sensory inputs. Thus it seems plausible that we are adapted to learn abstract concepts in the same multisensory manner. Several studies provide support for an embodied approach to abstract cognition, and show that extra-retinal feedback - specifically, sensorimotor feedback, either actual or imagined - enhances mathematical performance, reading comprehension, and syntax knowledge. Here, we examine multisensory learning of geometric information through the individual and combined contributions of vision and haptics (i.e., touch and proprioception). Specifically, we tested young adults and children (8-10 years old) on their ability to perceive geometric angles. Geometric perception was tested using a 'path

integration' 2-IFC paradigm in which two angles were presented in sequence and participants indicated the smaller of the two angles by choosing 'the fastest path home'. Testing occurred in one of three conditions: visual only (passive viewing of 'V-shaped' angular paths), haptic only (exploration of the angular path using hand movements), or bimodal, in which a combination of both inputs could guide perception. Findings from this study are consistent with previous studies suggesting vision and haptics contribute to shape perception in adults. The results from children suggest sensory dominance, and are consistent with previous reports suggesting developmental shifts in multisensory integration for small scale spatial perception relating to object perception, as well as large scale spatial perception for navigation. Importantly, by examining the effect of learning modality on angular magnitude estimation at varying ages, these findings will be used to inform geometric pedagogy and assistive educational technology for both sighted and visually impaired children.

#207 Premature birth and perinatal risk impact auditory object discrimination during late childhood

Hélène Turpin, Chrysa Retsa, FranÃ§ois Ansermet, Carole Müller-Nix, Sébastien Urben, Ayala Borghini, Micah Murray

Millions of premature children are born each year with high survival rates. However, little is known regarding how such abbreviated in utero development and atypical environmental experiences impact object representations across the senses. Previous research has shown that preterm born children are more prone to manifest developmental difficulties such as emotional dysregulation or cognitive impairments (Bora et al. 2011; Johnson et al. 2010). Likewise, studies would also suggest that emotional dysregulation may co-occur with impaired auditory discrimination (Mikkola et al., 2004; Theriens et al., 2004; Nosarti, 2013). To date, most prior work has been conducted in early childhood and did not take in consideration heterogeneity in the neonatal difficulties experienced by the preterm children. The aims of this study were twofold: 1) to identify consequences of premature birth on object representations that persist into late childhood; an age particularly susceptible to emotional dysregulation, and 2) to determine the impact of perinatal risk on the integrity of sensory and object processing in late childhood. To do this, auditory evoked potentials (AEPs) were recorded from preterm and full-term children who were now 10-year-olds. Preterm children were

likewise divided between those who had low vs. high perinatal risk, as measured with Schneiner and Sexton's (1991) perinatal risk inventory. Participants completed an auditory object recognition task, requiring the discrimination of sounds of living vs. man-made objects (Murray et al., 2006). AEPs were analyzed within an electrical neuroimaging framework and revealed group differences as well as differences in semantic discrimination of sounds of objects. These results provide novel insights on the long-lasting effects of prematurity on sensory representations that may in turn contribute to emotional dysregulation and cognitive impairments.

#208 Short latencies and integrative responses to naturalistic stimuli in the primate posterior cingulate cortex

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The involvement of the posterior cingulate cortex (PCC) in cognitive functions has been largely documented. Yet the PCC is a brain hub and has connections with multisensory areas. We therefore speculated that the PPC could also play a role in integrating sensory information across modalities. To test this hypothesis, we recorded neuronal responses of the PCC to naturalistic auditory, visual and auditory-visual stimuli, consisting of conspecifics, snakes and neutral stimuli (white noise), in two rhesus monkeys performing a fixation task. We confirmed stereotaxic coordinates of the target area by comparing MRI scans of the monkey brain with published brain atlases. We recorded the activity of 341 single units in the PCC. 196 neurons were responsive to at least one of the stimuli. We found that 27% of the neurons were visual unisensory, 15% were auditory unisensory and 56% were multisensory. To test a possible role of the PCC in multisensory integration, we calculated indices of amplification and additivity. The multisensory responses of the majority of PCC neurons reflected both a depression (64%) and sub-additive (98%) interactions. Sparseness and selectivity indices revealed that the majority of PCC cells are weakly selective and that stimuli encoding is highly scattered at the population level. Interestingly, the latencies of neuronal responses were very short (33 to 189 ms, median 62 ms) and did not differ between modalities. These very short latencies may be explained by afferent inputs from the thalamus and/or the striatum. This study shows for the first time that the PCC is a multisensory structure and even an integrator of sensory information and may act as a time calibrator of sensory information.

The PCC may be implicated in detection or in coarse and fast discrimination of sensory stimuli and may thus participate in the initiation of fast behavioral responses.

#209 Increased tendency for proximal proprioceptive errors in limb bisection for individuals with autism spectrum disorder is not mitigated by tool use

Brynna H. Heflin, John M. Tracy, Lisa E. Mash, Hayley Willer, Cassandra R. Newsom, Carissa J. Cascio

It is now well recognized that sensory and perceptual differences are central to autism spectrum disorder (ASD), and likely influence the social-communication and other behavioral symptoms that define autism. Previous studies have suggested that individuals with ASD are less susceptible to visual override of veridical proprioceptive information in paradigms such as the rubber hand illusion and motor learning tasks. We sought to further explore this phenomenon using a limb bisection task before and after a period of tool use. Tool use in typical adults has been shown to introduce distal errors in arm bisection. We hypothesized that individuals with ASD would not show this effect. We tested 38 individuals with ASD and a comparison group of 55 typically-developing (TD) individuals. We did not replicate the main effect of tool use; the TD group was similarly accurate before and after tool use training. However, we did see a clear effect of group in the pre-training bisection estimates: the ASD group was more likely to make proximal errors than the TD group initially. Further, rather than reversing this effect, tool use in the ASD group appeared to reinforce it: post-training estimates had more proximal error in the ASD group both relative to the TD group and to pre-training estimates in the ASD group. These results are consistent with the body of literature suggesting over-reliance on proximal proprioceptive input in ASD, and, more broadly, with the idea that body representation in ASD is resistant to expected plasticity by tool use or other input that typically extends the multisensory perceptual representation of the body. These differences may contribute to altered social perception and action in ASD.

#210 Multi-pronged effects of typical experience on multisensory object processing: Insights from selective attention and memory

Pawel J. Matusz, Rebecca Merkley, Solange Denervaud, Edouard Gentaz, Micah Murray, Gaia Scerif

The last two decades have highlighted the importance of development and experience in shaping visual selective attention and memory functions as well as in shaping multisensory processing. However, the visual studies provided no insights into the challenges linked to processing of multisensory information, while multisensory research focused predominantly on profoundly atypical experience (sensory or neurodevelopmental disorders). What remains unclear is how typical experience - linked to schooling or given object sub/categories - impacts processing of multisensory objects. We have previously shown that in a search for coloured visual shapes, school-entering children - but not adults or older children - are immune to audiovisual interference when the task becomes difficult (Matusz et al. 2015). These results suggested that "strongly automatic" processing of even highly-familiar multisensory objects hinges on experience, such as that of early schooling. Using a similar paradigm, we investigated how variable experience with object sub/categories shapes selective attention in multisensory settings. Young children have more experience with sound than visual stimulus formats of digits. Now, participants searched for predefined visual numerals, and we measured attentional "costs" and "benefits" of sound, shape and sound-shape distractors. Older children and adults were exclusively distracted by sounds, but younger children benefited from them. Thus, experience might render familiar stimuli initially beneficial and only then disruptive when allocating attention. Lastly, we employed a continuous visual "old/new" discrimination task with naturalistic objects to test how children's schooling shapes multisensory object processing. Children's memory, alike adults' (Murray et al. 2004), benefited from initial multisensory presentations. However, strength of these benefits could be predicted from multisensory benefits in a simple detection task only in children undergoing public, but not Montessori-style, schooling. These findings shed light onto the mechanisms whereby typical experience shapes how individuals process information on multisensory objects, and underline the benefits of adapting well-understood, rigorous visual paradigms.

#211 Peripersonal space boundaries in newborns

Giulia Orioli, Teresa Farroni

The Peripersonal Space (PPS) is the portion of space immediately surrounding the body, mediating all physical and social interactions between the body and the environment (Canzoneri et al., 2012; de Vignemont & Iannetti, 2015). Recent studies investigated the PPS dimensions using an audio- tactile integration task (Canzoneri et al., 2012; Teneggi et al., 2013). They showed that auditory stimuli speeded up the processing of concurrent tactile stimuli when they were perceived within a certain distance from the body, which could be considered the boundary of the PPS. We adapted this task in order to investigate the boundaries of the PPS in newborns. Newborns' attention was attracted to the centre of a screen by a continuously flashing light. Then a 2s lasting pure tone was presented together with a tactile stimulation (a paintbrush stroke on their forehead). As the tone finished, the newborns were presented with two peripheral visual targets and their saccadic reaction times (RTs) were recorded. The procedure was repeated 31 times, using tones perceived at different distances from newborns' body. Two groups of newborns participated, one of which experienced only the auditory stimulation, allowing us to disentangle the effect of the tactile and the auditory stimulation on the RTs. We hypothesized that newborns' RTs to the visual display following the audio-tactile stimulation would be significantly speeded up when the auditory stimulus was perceived within the PPS. The results showed a modulation of newborns' RTs depending on the perceived distance of the auditory stimulus in space, but only for the group of newborns who experienced the audio-tactile stimulation. The RTs pattern resembled quite closely that shown by adults (Canzoneri et al., 2012), suggesting that already at birth the PPS may exist as a delimited portion of space where multisensory integration is more efficient and that its boundaries can be determined.

#212 Differential attentional mechanisms for tactile subtizing and numerosity estimation

Yue Tian, Lihan Chen†

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To date, there remains debate whether there is common mechanism for sense of number, i.e, whether subtizing (with number of items less than or equal to 4) and

numerosity estimation(with number of items equal to or larger than 5) is (equally) subject to the attentional modulation. The evidence is especially lacking from tactile modality and is scare from cross-modal interaction perspective. In current study, we examined the sense of number of tactile events in both unisensory and cross-modal scenarios, either with focused or divided attention. Using Tactile Braille Displays, participants completed the following three tasks: 1) For unisensory and focused attention condition, participants reported the number (1~8) of the tactile pins presented on their right index finger. 2) For unisensory and divided attention condition, tactile pins were given simultaneously to both index fingers. In addition to reporting the number on right index finger, for the pins on the left index finger, participants made two-alternative forced choice (2-AFC)to answer whether the number of pins on the top area (display area separated symmetrically into two parts) was larger than the one on the down area. 3) Lastly, for the cross-modal (tactile-visual) and divided attention condition, during estimating the number of tactile pins on right index finger, observers made 2-AFC to report whether the upper area contained more visual elements than the down area had in a group of random visual dots (lasting 150 ms), which overlaid upon the tactile stimuli. We found that performance of estimation rather than subtizing was interfered in both unisensory and cross-modal dual tasks. Moreover, further test showed that individual working memory capacity modulated the effectiveness of attentional modulation. Overall, our study revealed that tactile numerosity estimation is subject to attentional modulation as well as the general working memory capacity.

#213 Cross-modal freezing effect: Evidence from eye tracking on audiovisual integration

Lihan Chen, Hsin-I Liao

Perceptual organization in auditory modality can have an effect on perceptibility in the visual modality. Typically, cross-modal facilitation effect has been observed in which an abrupt sound affects visual processing of a rapidly presented visual stimulus (the freezing phenomenon), making the visual target easily identified, though it is embedded in a cluttered visual scene (Vroomen & de Gelder, 2000). We hypothesize that the gaze duration would increase, as a potential physiological index for the 'freezing' effect in the cross-modal interaction scenario. To test this hypothesis, we used visual Ternus display and examined the classification of Ternus apparent motion (Element motion vs. Group motion) with or without the synchronous paired beeps. The Ternus display consisted of

two visual frames, each having two dots. When overlaid, the two frames shared one dot location at the center of the current visual field, with the other two dots horizontally located on the opposite side relative to the center. Dependent on the (perceived) visual interval between two visual frames, two distinct percepts were obtained: element motion (short visual interval such as 50 ms) and group motion (long interval such as 230 ms). We found that in the sound-present condition, dominant 'group motion' was reported. Accordingly, to our surprise, the pilot eye tracking data showed that the mean gaze duration for perceiving Ternus motion was reduced compared the one in baseline (no sound) condition. The results echoes the principle of 'inversed effectiveness", in which the synchronous beeps resolve the ambiguity of visual signals (associated with Ternus motion) and observers could make perceptual decisions even with less gaze duration upon the targets.

#214 Temporal reference and crossmodal assimilation

Lihan Chen, Xiaolin Zhou, Hermann J. Müller, Zhuanghua Shi

In a series of experiments, we revealed the roles of central tendency effect and recency effect in crossmodal temporal assimilation. We examined how the task-irrelevant preceding auditory events affects the visual motion percept induced by two imbedded Ternus-type (visual) display frames: element motion versus group motion. We demonstrated independent assimilations of both the ensemble (geometric) mean (central tendency effect) and the last interval (recency effect) of the auditory sequence upon the percept of visual motion. Specifically, longer mean (or last) interval elicited more reports of group motion (in line with the perceived long interval between two visual Ternus frames), whereas the shorter mean (or last) auditory intervals gave rise to more dominant percepts of element motion (in line with the perceived short interval between two visual frames). The impact of recency effect, compared with the impact of central tendency effect, is enhanced with extended sound sequence. Importantly, observers have shown dynamic adaption to the temporal reference for crossmodal assimilation: when the target visual Ternus stimuli were separated with a long gap interval between the preceding sound sequence, the central tendency effect by ensemble mean is reduced and even reversed- i.e., a temporal contrast effect rather than assimilation was observed. Our findings suggest a general temporal perceptual grouping principle underlying complex audio-visual interactions in everyday dynamic situations.

#215 One, two, three-It is quantity that counts: Multisensory benefit on odor object formation increases with the number of stimulated senses

Danja Porada, Christina Regenbogen, Jessica Freiherr, Johan N. Lundström

Object perception is usually the result of a complex interplay of several senses: we might see an object, hear and smell it. Visual, auditory and olfactory features are bound together to facilitate and improve object perception and to eventually create a percept that is of holistic nature. Unlike other sensory modalities, multisensory interactions in early olfactory cortex are relatively unexplored. It is not yet known whether binding of odor information with inputs from other sensory modalities occurs in primary olfactory cortex and whether increasing the number of contributing senses boosts the bound representation of the object. Our aim was to answer these questions by investigating the effect of multisensory stimulation on information processing in core olfactory areas: the anterior piriform cortex (APC), a low-level feature-related region, and the posterior piriform cortex (PPC), an object- related region. In an event-related fMRI paradigm, participants were exposed to uni-, bi-, and trimodal combinations of odors of familiar objects with congruent video sequences and/or sounds. To determine linear activation change related to the number of involved modalities, we extracted the activation in regions of interest (APC, PPC). We hypothesized that brain regions encoding odor objects (PPC) would show a linear activation increase with the number of modalities providing congruent object information, thus enabling better object representation. The results showed that activation in the odor object-related area (PPC) increased with the number of involved sensory modalities while activation in the lower-level odor area (APC) remained constant and independent of the number of modalities providing information. This suggests that, first, binding of multisensory information occurs in object-related brain regions of the primary olfactory cortex and that, second, increasing the number of contributing senses increases the boost of odor object formation. We conclude that odor-related multisensory signals influence odor object processing in the PPC in a quantity-dependent manner. Funding statement: Supported by grants from the Knut and Alice Wallenberg Foundation (KAW 2012.0141) and the Swedish Research Council (VRHS2014-1346).

#216 Prior knowledge of spatiotemporal configuration facilitates crossmodal response

Adele Diederich, Hans Colonius

A (saccadic) response to a visual target stimulus (e.g. flash) can be facilitated by an acoustic stimulus (e.g., white noise burst) appearing in spatiotemporal proximity, even though participants are instructed to ignore the auditory (non-target) stimulus in this focused-attention paradigm (FAP). A prominent view of the effect is that high spatiotemporal proximity makes it more likely that the participant interprets the visual and acoustic information as originating from the same object, thus providing a “common cause" for an event. Moreover, prior knowledge, or expectation, about the location of a target stimulus speeds up stimulus detection, and the validity of a cue presented in spatiotemporal proximity has been shown to be a modulating factor. However, the role of prior knowledge in (saccadic) behavior within a cross-modal context, with target and non-target defined in different modalities, has received relatively little attention. Here we test the hypothesis that (saccadic) reaction time facilitation in the presence of a non-target increases with the level of prior knowledge of spatial alignment of a target with the non-target. Two experiments were conducted with saccadic and manual responses as dependent variables. Consistent with the hypothesis we found mean RTs in the 80% prior knowledge condition to be faster than mean RT in the 20% condition. Fitting the time window of integration (TWIN) model to the data allowed further insight: keeping all model parameters constant across the three levels of prior knowledge, with the exception of the window width parameter, the observed changes in facilitation could be captured by appropriate changes in the window width. That is, the modeling results suggest that, when prior knowledge points to a frequent occurrence of spatial alignment, or “unity" of visual and acoustic events, participants adjust their time window width to a larger value than in the case of “rare" alignment.

#217 The interdependence of visual salience and audiovisual synchrony on auditory contrast detection

D.N. Briggs, H.M. Chow, V.M. Ciaramitaro

IntroductionOur senses afford us unique but often complementary experiences of our environment, which can be integrated into a unified percept. The strength of multisensory integration has been shown to depend on spatial coincidence, temporal

synchrony, and relative salience between sensory stimuli (principle of inverse effectiveness). Recently, Fister and colleagues (2016) showed that stimulus intensity could alter the temporal binding properties of synchronous audiovisual stimuli such that audiovisual stimuli were integrated over a wider temporal window when stimulus salience was weaker. We examined how salience and synchrony interact by quantifying auditory detectability as visual intensity and audiovisual synchrony were altered. MethodsParticipants were presented with auditory white noise, modulating at 1Hz at one of five contrasts (32-34dB) against a 35dB background noise, from a speaker right or left of center. A task-irrelevant visual stimulus was also presented and modulated at 1Hz at one of four salience levels (75, 90, 150, 180 cd/m2) while fluctuating in-phase (synchronous) or out-of-phase (asynchronous) with the auditory stimulus, or did not modulate and remained at 60 cd/m2 in a baseline condition. These three possible audiovisual conditions were randomly interleaved. Participants judged where the sound originated from by looking to that location as recorded via eye-tracker. Percent correct performance across auditory contrasts, for each visual salience and audiovisual condition, was fit with a Weibull to estimate auditory threshold (75% correct performance). Results/ConclusionWe found a significant benefit, lower auditory threshold, for the in-phase relative to out-of-phase condition when visual salience was low (90 cd/m2) in contrast to a significant out-of-phase, relative to in-phase, benefit when visual salience was high (180 cd/m2). These results suggest that the relative salience of visual information can not only alter the magnitude of audiovisual integration but switch the interaction from an in-phase to out-of-phase benefit.

#218 The impact of singing on multisensory integration in children with Autism Spectrum Disorder

Alexander Tu, Wayne Kuang, Julie Conrad, Pooja Santapuram, Jacob I. Feldman, Emelyne Bingham, Tiffany G. Woynaroski

Children with autism spectrum disorder (ASD) show reduced multisensory integration of audiovisual speech stimuli when presented with spoken “McGurk"stimuli. Such differences in multisensory integration may underlie language impairments in children with ASD. We hypothesize that children with ASD will show enhanced multisensory integration for sung tokens, which offer more salient visual and auditory cues. We are recruiting 20, 5-17 year oldchildren with ASD and 20 TD childrenmatched on

chronological age, sex, and IQ. Participants will be presented with auditory-only, visual-only, and congruent audiovisual syllables, as well as incongruent McGurk stimuli in two conditions (spoken, sung). After each presentation, the participant will report what they perceived by pushing a button on a serial response box. We will assess between-group differences in auditory-only, visual-only, and congruent audiovisual accuracy, as well as the magnitude of multisensory integration for incongruent McGurk stimuli in the spoken and sung conditions and explore associations between measures of multisensory integration and language ability according to group. Data collection will be complete prior to IMRF. Preliminary results indicate TD children do not exhibit any significant difference in perception of the McGurk effect in response to sung versus spoken stimuli, consistent with previous research. We expect children with ASD will show reduced accuracy in identifying visual-only and congruent audiovisual syllables, as well as reduced integration for incongruent audiovisual syllables presented in the spoken condition relative to TD controls. However, we anticipate that children with ASD will show increased identification accuracy and integration for the analogous “sung" syllables, such that they will not differ from TD peers in “sung" conditions. Findings would indicate that music may be a modality by which we might increase multisensory integration, and perhaps even support language learning, in children with ASD.

#219 Perceptual training in children with autism spectrum disorder: A proposed study utilizing single case research design

Julie G. Conrad, Jacob I. Feldman, Alex Tu, Wayne Kuange, Mark T. Wallace, Tiffany G. Woynaroski

Recent studies have shown that individuals with autism spectrum disorder (ASD) exhibit atypical responses to multisensory stimuli; specifically, they present with wider temporal binding windows (TBW) for audiovisual speech in comparison to typically developing peers (Baum, Stevenson, & Wallace, 2015). Recent studies have also reported training programs are capable of narrowing the TBW in typically developing (TD) adults (e.g., Powers, Hillock, & Wallace, 2009). The present study will examine whether multisensory perceptual training programs may normalize TBWs and generalize to improvements in children with ASD. The proposed study will utilize a single case research design, which is experimental in nature. Single case designs document causal/functional relations between independent and dependent variables (IV and DV) via continuous measurement

of DVs (Horner et al., 2005). This study will specifically use a multiple baseline across participants design, which has at least three participants participate in baseline, intervention and maintenance conditions. The introduction and withdrawal of the IV is time-lagged; some participants remain in an extended baseline to rule out alternative explanations for the effect. This study will utilize a multisensory training paradigm previously studied in TD adults (Di Niear, 2016). The primary dependent variable, upon which treatment decisions will be made, is TBW for audiovisual speech. More distal effects on speech perception and autism symptomatology (e.g., sensory responsiveness, social cognition, communication) will be measured as well. Participants will undergo regular EEGs and fMRIs to explore the possible collateral effects of the treatment on neural measures that may mediate effects of treatment. The implications of the proposed study will be discussed. Should the hypothesis that the training narrows TBWs and leads to distal gains in autism symptomatology be born out, a treatment study utilizing group research design will be pursued.

#220 Looking predicts vocal complexity and language development in infants at risk for ASD

P. Santapuram, J. Feldman, S. Bowman, A. Morgan, B. Heflin, A. Augustine, B. Keceli-Kaysili, C. Cascio, T. Woynaroski

Theory and recent research suggest that linguistic development relies on audiovisual attention in conjunction with early experiences. Specifically, typically developing infants shift their gaze from the eyes to the mouth in the second half of the first year of life, presumably to facilitate integration of auditory and visual elements of speech. This shift corresponds with the timing of qualitative changes in vocal complexity that are viewed as pivotal to linguistic development, such as the onset of canonical babbling. Gaze patterns to audiovisual speech differ in children who are diagnosed with or at heightened risk for ASD relative to their TD peers. This pilot study will prospectively follow infants at high risk for ASD to determine whether early differences in gaze to audiovisual speech may be useful for predicting pre-linguistic and linguistic deficits in this population. Infants at high risk (HR; siblings of children diagnosed with ASD) versus relatively low risk (LR; siblings of TD children) for ASD ages 6-18 months from primarily English-speaking households will be recruited. Gaze patterns to eye versus mouth regions will be measured as infants view videos of a woman speaking in infant-directed speech in their native language (English).

Vocal complexity will be measured in two full-day audio recordings, collected on consecutive days using LENA digital language processors. Parents will report children's early word use on the MacArthur-Bates Communication Development Inventories checklist. Data collection is ongoing. We anticipate having preliminary results by IMRF. We hypothesize that proportion of looking time to the mouth region will predict greater vocal complexity and larger spoken vocabulary, at least in infants at HR for ASD. If our hypotheses are born out, we will have identified a novel measure that may facilitate earlier identification and intervention of language impairments in infants at heightened risk for ASD.

#221 Correlations between multisensory integration and sensory responsiveness in children with and without Autism Spectrum Disorder

Wayne Kuang*, Jacob Feldman*, Julie Conrad, Alexander Tu, Pooja Santapoorum, Lawand Yaseen, Mark T. Wallace, Tiffany G. Woynaroski

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Research has shown that children with autism spectrum disorder (ASD) show differences in multisensory integration and in behavioral responses to sensory stimuli (sensory responsiveness) relative to typically developing (TD) peers. Differences in sensory responsiveness may include reduced responding to sensory stimuli (hyporesponsiveness), exaggerated responding (hyperresponsiveness), or craving of sensory experiences (sensory seeking). This study explored correlations between multisensory speech perception/integration and sensory responsiveness in children with ASD and TD controls. Participants were 8-17 year old children, 18 ASD and 18 TD, matched on age, sex, and IQ. To assess multisensory speech perception/integration, participants were randomly presented with CV syllables in auditory-only, visual-only, matched AV, and mismatched AV (McGurk) conditions. To evaluate the effects of temporal asynchrony on binding of multisensory speech information, the timing of mismatched AV stimuli was shifted so that the visual stimulus preceded the auditory stimulus by seven stimulus onset asynchronies. Sensory Experiences Questionnaire and Sensory Profile Caregiver Questionnaire were used to measure sensory responsiveness. Several indices of multisensory speech perception/integration were associated with sensory responsiveness. Hyporesponsiveness correlated with temporal binding window (TBW) size (r = .39), as well as auditory-only (r = - .35), visual-only (r = - .48), and matched AV (r = - .51) accuracy. Hyperresponsiveness correlated with visual-only (r = -

.52) and matched AV (r = - .36) accuracy. Sensory seeking correlated with TBW size (r = .35) and auditory-only (r = - .29), visual-only (r = - .29), and matched AV (r = - .43) accuracy. Associations were not moderated by group. This is the first study to demonstrate that differences in multisensory speech perception/integration covary with atypical patterns of sensory responsiveness. Additional work will determine whether differences in multisensory speech perception temporally precede, or are causally related to, differences in sensory responsiveness, or vice versa.

#222 Building auditory spatial metrics elicits stronger early occipital response in sighted than in blind individuals

Claudio Campus, Giulio Sandini, Monica Gori †

† presenting author

Much evidence points to interaction between vision and audition at early cortical sites. However, the functional role of these interactions and their modulation due to sensory impairment is not yet understood. EEG was recorded in 16 blindfolded sighted and 16 blind naiÌˆve subjects performing an auditory bisection task to a sequence of 3 sounds where the middle sound could be delivered at two different spatial position and two different temporal lags independently. Our data show that, when a metric representation is required, representation of sounds in space elicited in sighted but not in blind individuals a response mimiching C1 ERP component which is usually elicited in visual tasks. The observed specific early occipital response to sound was selective for the sound spatial position, occurred only when the sighted and not the blind subjects estimated spatial separation and was absent for both groups when estimating temporal separation. We suggest that this early occipital processing of sounds might be mediated by visual experience. The lack of vision might impact on the construction of a multi-sensory maps projected on the retinotopic maps used by visual cortex.

#223 Distinct but not independent peripersonal space representations around different body parts: a neural network model

Matteo Vissani, Andrea Serino, Cristiano Cuppini † , Elisa Magosso

† presenting author

The peripersonal space (PPS) is represented by a dedicated system of multisensory neurons with tactile receptive field on a body-part (hand, arm, trunk, head, etc.) and visual/auditory receptive field anchored to the tactile one and extending limitedly in depth. A recent study (Serino et al. Sci Rep 2015) estimated behaviourally the properties of the PPS representation around a body-part by measuring the tactile reaction time while a sound was at different distances from the body-part. Results evidenced that different body-parts (the hand and trunk) have distinct but not independent PPS representations. The hand-PPS exhibited properties different from the trunk-PPS when the hand was placed far from the trunk, while it assumed the same properties as the trunk-PPS when the hand was placed near the trunk. Here, a neural network model is presented to help unrevealing the underlying neurocomputational mechanisms. The model includes two subnetworks, devoted to PPS representation around the hand and trunk, respectively. Each subnetwork contains a pool of multisensory audio-tactile neurons communicating, via excitatory feedforward and feedback synapses, with two areas of unisensory neurons: the latter code the tactile surface of the corresponding body-part and the auditory space around the same body-part (in body part-centred coordinates). The multisensory neurons in the two subnetworks have different properties. The two subnetworks interact assuming that the feedback synapses from the trunk related-multisensory pool protrude into the hand tactile unisensory area; moreover, a pool of proprioceptive neurons coding the hand position modulates the strength of the feedback synapses from the two (hand and trunk) multisensory pools to the hand tactile unisensory area. Network tactile reaction times are decoded from the neuronal responses in the unisensory tactile areas. The network reproduces behavioural data of distinct handPPS and trunk-PPS and their relationship; moreover, it provides novel testable predictions to validate or revise model hypotheses.

#224 My peri-personal property: Exploring the effect of object ownership on peripersonal space

Ivan Patané, Claudio Brozzoli, Eric Koun, Romeo Salemme, Francesca Frassinetti, Alessandro Farnè

Stimuli from different sensory modalities occurring on or near our body parts are integrated in a multisensory representation of the space surrounding us called peripersonal space (PPS). This body centered coding of space is thought to be involved in the motor control of goal-directed actions, as voluntary acting on objects triggers online remapping of coding of multisensory-motor PPS. As grasping our own or somebody else's object has been recently reported to alter movement kinematics, here we tested whether the concept of object ownership may differentially modulate PPS when grasping or merely observing a partner grasping the same owned object. Healthy participants were asked to take turns to reach and grasp with their right hand a glass- shaped object placed upon a transparent saucer. On a trial-by-trial basis, the saucer could light up in one of three different colours, thus randomly determining ownership (experimenter's, partner's or one's own) of the to-be-grasped object. PPS was probed both before movement start and at movement onset by a visuo-tactile task in which spatially incongruent visual distractors (embedded in the object) interfere with discriminating the location (index or thumb) of a tactile stimulus delivered on the acting hand. This experimental design will allow us to identify whether visual distractors affects perception of touches more strongly during the action onset than before the beginning of the overt movement as a function of the different property conditions. The results will be discussed in the theoretical framework of the PPS plasticity.

#225 Neural mechanisms underlying audio-visual crossmodal associations

Stephanie C. Boyle, Robin A. Ince, Christoph Kayser

While the brain predominately integrates sensory cues depending on their spatial and temporal congruency it also embodies more implicit associations, such as between pitch and size 1. However it remains unclear how such associations are reflected in the brain, or when during a trial (if at all) neural activity is modulated by the perceived congruency of sensory cues. We investigated these questions using a modified version of the implicit association test. On each trial subjects (n=20) were presented with one stimulus (high

tone, low tone, small circle or large circle) and asked to identify which they saw as quickly and as accurately as possible. Importantly, on each block the assignment of the auditory stimuli was changed to generate “congruent” and “incongruent” pairings. Congruent pairings were defined as a low tone paired with a large circle, or a high tone paired with a small circle. The behavioural results show that a crossmodal association between pitch and size exists, with most subjects responding faster to congruent pairings of stimuli than incongruent pairings. For the EEG data single-trial analysis based on multivariate decoding and information theoretic analysis was used to uncover EEG components that best discriminated between the two acoustic / visual stimuli. Linear modelling was used to assess when these EEG components were predictive of reaction times on a single-trial basis, and when they were modulated by congruency. Our data suggest that neural activity early after the stimulus onset (<150ms) is modulated by the perceived congruency of the stimuli and is predictive of reaction time. As a result, our data support an early and short-latency origin of cross-modal associations.

#226 Contextual determinants of cue binding or separation in multisensory time perception

Lucy Lai, Jeffrey M. Yau

How the brain uses contextual information in a decision to bind or separate cues is a fundamental question in sensory neuroscience. Duration is an ideal feature for studying context-dependent multisensory perception, as elapsed time can be perceived by multiple sensory systems. In a series of behavioral experiments, we tested how sounds influence the perceived duration of a co-occurring tactile stimulus. We found that distractor sounds, which participants were instructed to ignore, exerted both attractive and repulsive biasing effects on tactile duration judgments. These effects were reliable in individual participants and consistent across multiple timing ranges. We modeled these results using a two-step Bayesian inference model that computes a perceptual duration estimate following an initial decision to bind or separate duration cues. Critically, this decision depends on both sensory context and intrinsic biases in the perception of audio-tactile timing signals. After this decision is made, the resulting perceptual estimate is computed using sensory evidence and prior knowledge of the coupling statistics between audition and touch. The model predicts both attractive and repulsive biases, and we validated its predictions in a subsequent experiment by demonstrating that the pattern of

bias changes when altering the sensory context by embedding the duration cues in noise. These results imply that the nervous system computes multisensory duration estimates that are conditioned on probabilistic decisions to bind or separate cues. Our model provides a unified framework for understanding the extensive range of perceptual outcomes that result from multisensory interactions.

#227 The developmental trajectory of auditory-tactile simultaneity perception

Brendan Stanley, Yi-Chuan Chen, Terri L. Lewis, Daphne Maurer, David I. Shore

Simultaneity perception forms one of the fundamental factors supporting multisensory integration. Such perception occurs when two signals, each from a different modality, are perceived as a single event. The temporal window within which integration occurs narrows progressively with age. We measured the developmental trajectory of the auditory-tactile simultaneity window in right-handed individuals using a simultaneity judgment task. The auditory stimulus was a white noise burst presented through closed-ear headphones; the tactile stimulus was a tap to the right index finger. Pairs of sounds and taps were separated by one of 13 stimulus onset asynchronies (SOAs). Participants judged whether the stimulus pairs were presented synchronously or asynchronously. Four age groups were tested (7-, 9-, 11-year-olds and adults). Seven-year-olds made more simultaneous responses than adults when the sound led by more than 200ms, and when the tap led by more than 300ms, but made fewer simultaneous responses when both were presented simultaneously. Nine-year-olds made more simultaneous responses than adults when either the sound or tap led by 800ms or 1200ms. Eleven-year-olds performed like adults at all SOAs. Using a bootstrap routine (Alcalá-Quintana & García-Pérez, 2013, Behav. Res. Methods), the estimated point of subjective simultaneity (PSS), located on the tactile leading side, was adult-like by 7 years of age. The width of the simultaneity window narrowed to adult levels by 9 years of age but the response errors continued to decline until 11 years of age. These results show a long developmental trajectory for auditory-tactile simultaneity perception, similar to that reported for visual-tactile and auditory-visual simultaneity (Chen et al., 2015, Perception; Chen et al., 2016. J. Exp. Child Psychol.). However, auditory-tactile was more similar to visual-tactile simultaneity perception in that they both show errors at long SOAs to a later age than does auditory-visual simultaneity perception.

#228 Sounds facilitate visual completion

Ruxandra Tivadar, Nora Turoman, Pawel J. Matusz, Micah M. Murray

Everyday vision must surmount impoverished viewing conditions to enable figure-ground segregation, object localization, and recognition. An example of such mid-level vision is border completion across physically-absent contrast gradients. Such illusory contours (ICs) have been extensively studied in laboratory settings, with ERP correlates of ICs sensitivity at ~100-150ms post-stimulus onset. It is now well-established that multisensory processes can influence both low-level vision (e.g. detection) as well as higher-level object recognition. It is unknown if mid-level vision benefits from auditory inputs. This would be important, given evidence for impaired IC perception in sight-restored individuals after cataract removal who nonetheless present clinically normal vision. We reasoned that sounds would impact completion processes supporting IC sensitivity. Participants viewed arrays of black pacmen inducers on a dark grey background that were oriented to form ICs or no-contour (NC) counterparts in a 2x2x2 within-subject design. Two varieties of inducers were used to differentiate potential effects of sounds on completion processes as opposed to more general brightness enhancement of the inducers; that occurs for modal, but not amodal inducer stimuli. An uninformative sound was presented on half of the trials. Participants indicated IC presence vs. absence while 128-channel EEG was recorded. We replicated prior ERP findings of IC sensitivity at ~150ms and ~300ms. Crucially, IC sensitivity was enhanced by uninformative sounds; there was a significant interaction between IC/NC and sound presence at ~150ms post-stimulus onset. Sounds thus facilitated visual completion. The 3-way interaction was significant only at ~300ms, suggesting that the effect of sounds on IC sensitivity at ~150ms was indistinguishable across both modal and amodal completion. Our findings significantly extend prior work documenting the presence of multisensory interactions during early stages of stimulus processing by indicating that multisensory interactions can facilitate mid-level vision and may thus be a strategy for visual rehabilitation. This research has been supported by grants from the Swiss National Science Foundation (320030_169206 and 320030-149982) and Carigest SA to MMM as well as by a grant from the Pierre Mercier Foundation to PJM.

#229 Visual modulation of deep layer neurons in mouse auditory cortex

Ryan J. Morrill, Andrea R. Hasenstaub

Cortical multisensory integration is traditionally held to occur in higher-order association areas; however, work over the past decade suggests that even primary sensory cortex may receive and integrate information from other modalities (Wallace et al., 2004; Ghazanfar & Schroeder, 2006). In a variety of organisms, auditory cortex responds to stimuli from other modalities, both in conjunction with and independent of acoustic stimulation (Kayser et al., 2008; Bizley et al., 2007). Despite the importance of the mouse as a systems neuroscience model for circuit dissection, it remains unknown to what degree visual stimuli modulate or drive responses in mouse auditory cortex. Mouse auditory cortex receives inputs from visual cortical areas which terminate both in deep and superficial layers (Banks et al., 2011), suggesting that modulation of activity might also be layer-specific. Here we describe the temporal and laminar organization of visual influences on neural firing in the auditory cortex of the awake mouse, using multisite probes to sample across multiple cortical layers. We demonstrate that these recording sites are located in auditory cortex based on characteristic neural responses to click trains and pure tones of varied frequencies and sound levels. We then determine the laminar location of recording sites through electrode track tracing with fluorescent dye and optogenetic identification using layer-specific markers. We find that spiking responses to visual stimulation occur in the deep layers of auditory cortex. Visual modulation of firing rate occurs more frequently at areas with secondary-like auditory responses than those with primary-like responses. We further find auditory cortical responses to drifting gratings are not substantially orientation-tuned, unlike characteristic visual cortex responses. We speculate as to the role of this finding in auditory processing and its generalizability to other cortical systems.

#230 The critical role of vestibular inputs in tactile remapping

Kaian Unwalla, Michelle L. Cadieux, David I. Shore

In order to localize a touch to the hand in coordinates external to the body surface, we must integrate information from multiple senses including vision, touch, and proprioception. This integration is harder when the hands are crossed over the midline, which produces a profound deficit in determining the order of two tactile events applied

one to each hand. The present investigation explores the role of the vestibular system in this tactile temporal order judgement task. Participants adopted one of three different body positions: upright, lying on their back, or lying on their side. Participants performed tactile temporal order judgments with their hands uncrossed and crossed. We observed a crossed-hands deficit-worse performance when the hands were crossed-in all postures, but the magnitude of the deficit was different. In Experiment 1, we found a reduced deficit when participants laid on their back compared to sitting upright. Experiment 2 investigated the influence of lying on their side, which again reduced the crossed-hands deficit. Finally, in Experiment 3 we directly compared the effect of lying on their back to lying on their side. A smaller deficit was observed when lying on their side. Taken together these data suggest a critical role for the vestibular system in localizing tactile information. Further, these results have implications for how we model the remapping process and support the conclusion that both reference frames-internal and external-contribute to the final output from the tactile remapping process.

#231 Comparing audiovisual semantic interactions between linguistic and non-linguistic stimuli

Yi-Chuan Chen, Charles Spence

We examined the time-courses of the crossmodal semantic congruency effects elicited by naturalistic sounds or spoken words on the processing of visual pictures and printed words. Auditory primes were presented at seven stimulus onset asynchronies (SOAs) with respect to the visual targets, ranging from auditory leading by 1000 ms to auditory lagging by 250 ms. Participants made speeded categorization judgments (living vs. non-living) regarding the visual targets. Three common effects were observed for both types of visual targets: Both naturalistic sounds and spoken words induced a slow facilitatory effect when leading by 250 ms or more in the congruent condition, but induced a rapid inhibitory effect when leading by 250 ms or less in the incongruent condition. Only spoken words that did not match the visual targets elicited an additional inhibitory effect when leading by 100 ms or when presented simultaneously. As compared to non-linguistic stimuli, the priming effects associated with linguistic stimuli occurred over a wider range of SOAs, and the interactions occurred at a more specific level of the category hierarchy (i.e., the basic level) than required by the task. These results suggest different routes to semantic access: Linguistic stimuli accessed meaning mediated by

the lexical representation that activated semantic representations at the corresponding level of the category hierarchy precisely, whereas non-linguistic stimuli accessed their meaning rapidly and directly, but first accessed meaning at a higher-level of semantic hierarchy. We propose a comprehensive framework to provide a dynamic view regarding how meaning is extracted during the processing of linguistic and non-linguistic stimuli presented in the visual and auditory modalities, therefore contributing to our understanding of the human semantic system.

#232 An electroencephalography investigation of the effects of attention on crossmodal temporal acuity

Kathryn K. Hirabayashi, Zoii Barnes-Scott, Samantha L. Papadakis, Leslie D. Kwakye†

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Our perception of the world hinges on our ability to accurately combine the many stimuli in our environment. This multisensory integration is highly dependent on the temporal relationship between unisensory events and our brain's ability to discern small timing differences between stimuli (crossmodal temporal acuity). Our previous research investigated whether attention alters crossmodal temporal acuity using a crossmodal temporal order judgment (CTOJ) task in which participants were asked to report if a flash or beep occurring at different time intervals appeared first while concurrently completing a visual distractor task. We found that increasing the perceptual load of the distractor task led to sharp declines in participants' crossmodal temporal acuity. The current study uses electroencephalography (EEG) to understand the neural mechanisms that lead to decreased crossmodal temporal acuity. Participants completed a CTOJ task as described above while EEG activity was recorded 64 scalp electrodes. EEG activity was averaged based on the onset of the flash producing an event-related potential (ERP) waveform for each perceptual load level and stimulus onset asynchrony (SOA) combination. Preliminary data analysis suggests that increasing perceptual load most strongly influences the amplitude of the N1/P2 complex in response to the flash across parietal electrodes. This suggests that decreases in crossmodal temporal acuity with increasing visual load may be mediated by alterations to visual processing. This line of research could ultimately help our understanding of the disruptions in temporal acuity often found in attentional disorders.

#233 Dynamic cortical interactions mediate crossmodal object recognition in rats

Boyer D. Winters, Derek L. Jacklin, Alphonse Potvin, Jacob M. Cloke, Michelle Moon, Emily Boughner

Rats, humans, and monkeys demonstrate robust crossmodal object recognition (CMOR), identifying objects across sensory modalities. We have shown that rats' performance of a spontaneous tactile-to-visual CMOR task requires functional integration of perirhinal (PRh) and posterior parietal (PPC) cortices, which seemingly perform visual and tactile object feature processing, respectively. Orbitofrontal cortex (OFC) also contributes when memory retention is taxed. However, research with primates suggests that object representations change depending on the nature of experience with those objects. We tested this hypothesis in rats using a modification of the CMOR task in which multimodal pre-exposure to the to-be-remembered objects significantly facilitates performance. In the original CMOR task, with no pre-exposure, reversible lesions of PRh or PPC produced patterns of impairment consistent with modality-specific contributions; PFC lesion effects suggested an object encoding role, possibly through interactions with PPC. Conversely, in the CMOR task with pre-exposure, neither PPC nor OFC lesions had an effect, whereas PRh involvement was robust, proving necessary for phases of the task that did not require PRh activity when rats did not have pre-exposure; this pattern was supported by results from c-fos imaging, which indicated corresponding PRh neuronal activity following pre- exposure. We suggest that multimodal pre-exposure alters the circuitry responsible for object recognition, in this case obviating the need for OFC or PPC contributions and expanding PRh involvement, consistent with the polymodal nature of PRh connections and results from primates indicating a key role for PRh in multisensory object representation. These findings have significant implications for our understanding of multisensory information processing, suggesting that the nature of an individual's past experience with an object strongly determines the brain circuitry involved in representing that object's multisensory features in memory.Acknowledgements: Supported by NSERC.

#234 Age related changes in sensory-motor processing

Carlos Carrasco, Fang Jiang, Tiziana Vercillo

The perceived temporal interval between a motor action and its sensory consequence can be altered by exposure to a delay between the two events. Sensory-motor

recalibration is essential in everyday life to overcome temporal differences in the physical propagation of external stimuli and keep causality judgments accurate. However, age-related decline in cognitive function and sensory/motor processing might compromise sensory-motor integration and recalibration. Using an adaptation paradigm followed by a temporal order judgement (TOJ) task, we investigated the effect of aging on sensory-motor recalibration. Young and elderly adults adapted to a 200 and 500 ms delay (in separate blocks) between a button press and a visual feedback. After adaptation, participants pressed a button in response to a visual cue and were asked to judge whether the visual stimulus occurred before or after their motor acts. The visual stimulus appeared either in the center or in the periphery of the visual field. In young adults, we only observed a recalibration effect after adaptation to a 200 ms delay, and when the visual stimulus was presented in the center. Elderly participants did not calibrate the timing of motor acts and visual feedback in any conditions. Moreover, we observed an increase in thresholds and visual reaction times (RT) with age. Thresholds and RTs were also positively correlated to one another, suggesting that the aging process might affect motor and/or sensory processing, resulting in a less flexible sensory-motor integration.

#235 Vibrotactile stimulation of fingertips via tactile displays affects the perceived surface and shape properties of objects

F. Sorgini, L. Massari, J. D'Abbraccio, E. Palermo, A. Menciassi, P.B. Petrovic, A. Mazzoni, M.C. Carrozza, F.N. Newell, C.M. Oddo

Despite our knowledge of how information provided to human fingertips facilitates the haptic description of objects, mechanisms which regulate the encoding of this information are not well understood. A better understanding would provide a useful guide for the development of wearable tactile displays for telepresence activities, and the provision of tactile sensory substitution in individuals with audio/visual impairments. Here we tested how the processing of tactile information relating to an object's surface and shape properties occurs and in particular, whether vibrotactile stimulation is effective in delivering this tactile information. In two separate studies participants discriminated surface properties (stiffness in Experiment 1; texture in Experiment 2) and shape (Experiment 2 only) based on a 2-AFC design. A vibrotactile glove, equipped with piezoelectric elements on fingertips, was used to deliver surface information in both experiments. Experiment 1 was performed across two laboratories (Italy and Ireland)

using telepresence. In one laboratory, information from a mechanical, sensing platform with indentations of 6 samples of silicon rubbers with different hardness was acquired. This was converted in real time using neuronal spiking models to simulate surface stiffness via vibrotactile stimulation presented to the hand of the participant in the second laboratory. In Experiment 2, participants discriminated between two (real) object shapes, differing in curvature, while stimulated by vibrotactile information representing different surface textures. Preliminary results of Experiment 1 suggest that vibrotactile stimulation can effectively simulate surface stiffness when a neuronal spiking model is used, with discrimination accuracy around 80%. The results of Experiment 2 suggest interactions between the perception of object shape (curvature) and surface texture when texture information is presented via vibrotactile stimulation. Our findings have implications on our understanding of how tactile information about shape and surface material is integrated in the perception of objects, and for the design of more effective haptic devices.

#236 Influence of spatial congruence in the sound-induced flash illusion using competing sounds.

Lindsey R. Kishline, Adrian K.C. Lee, Ross K. Maddox

Spatial congruence has been regarded as one of the fundamental rules in promoting multisensory integration, despite conflicting reports of its influence on the perception of integration across different types of tasks. The importance of auditory and visual spatial congruence during the sound-induced flash illusion (SIFI) has also been shown to be variable, likely depending on the presence of stimulus competition and directed spatial attention. To assess the influence of spatial coincidence on multisensory integration we manipulated the spatial congruence and proximity of two competing auditory stimuli and a single visual stimulus using the SIFI. Participants were presented with two timbrally distinct and concurrent auditory stimuli which were presented at different spatial locations consisting of either one or two beeps. A single visual stimulus, always spatially congruent with one of the auditory stimuli, was composed of either one or two flashes. On every trial one of the auditory stimuli matched the number of visual events, and the other did not. In one block of the experiment, a visual symbolic cue preceded each trial indicating the location -- central, left or right -- the visual flash would occur. In another block, there was no preceding visual cue. Participants were asked to maintain center

fixation and report the number of flashes that they perceived. We compare the results with and without cueing to examine the effect of spatial attention and auditory competition during the multisensory illusion. Funding: T32-DC005361 (LRK), DGE-1256082 (LRK), K99DC014288 (RKM), R01DC013260 (AKCL)

#237 Visuotactile synchrony perception in own-body contexts

Robert A. Keys, Anina N. Rich, Regine Zopf

Perceiving one's own body - the bodily-self - is essential for environmental interaction. Bodily-self perception involves integrating multisensory cues, such as the anatomical plausibility of viewed body orientation and form, and the spatiotemporal congruence of crossmodal information. How different cues are integrated is an open question that also has implications for understanding how context may affect multisensory processing in general. For instance, previous research shows that bodily-self cues modulate visuotactile temporal perception: Ide & Hidaka (2013) found that viewing anatomically plausible hand images (oriented upright, i.e., typical for one's own hand) reduces the precision of visuotactile temporal order judgments (TOJ) compared to implausible images (rotated 180Â°). This suggests that bodily-self cues widen the temporal binding window for visuotactile stimuli. However, it is unclear whether these cues also modulate the ability to detect whether two stimuli are asynchronous, which would indicate a general, rather than task specific, mechanism for near-body visuotactile time perception. In two experiments, participants viewed plaster hands in plausible or implausible orientations. We investigated whether viewed hand orientation affects detection of asynchrony between vision and touch. In one experiment, the hands were stroked to induce the rubber hand illusion to explore the effect of body-ownership. We used the method of constant stimuli and a two-interval forced-choice task. Trials comprised two intervals, each with a visual stimulus (LED flash on the plaster hand) and a tactile stimulus (tap to fingertip of the participant's hidden hand). The visuotactile stimuli were synchronous in one interval and asynchronous in the other (delay: 40~280ms). Bayesian analyses show that our data provide strong evidence that bodily-self cues do not affect visuotactile asynchrony detection. Thus, although own-body perception may affect the window for temporal integration as measured by TOJ, it does not affect sensitivity to visuotactile asynchronies.

#238 Audiovisual integration in the depth dimension: an asymmetrical effect of distance on the temporal profile of multisensory gain and binding

Nathan Van der Stoep, Jean-Paul Noel, Kahan Modi, Mark T. Wallace

The integration of information across sensory modalities is dependent on the characteristics of the stimuli to be combined. That is, the closer in space and time auditory and visual stimuli are from one another, the more likely the stimuli will be integrated and lead to a single multisensory percept. Multisensory integration (MSI) can lead to multisensory response gain that often cannot be explained by statistical facilitation. These principles are well established and studied in isolation, but their interaction is less well understood, particularly in the depth dimension. Whereas previous findings indicate larger temporal binding windows (TBW) in near space, multisensory response gain seems larger in far space. In the current study, participants performed both an audiovisual redundant target effect task and a simultaneity judgment task in near and far spaces. This allowed us to scrutinize multisensory response enhancement and temporal binding as a function of stimulus- observer distance. The results demonstrate that while multisensory binding is exacerbated at larger temporal asynchronies in near relative to far space, the range of reaction times over which multisensory gain is observed was greatest in far space. Taken together, the results seemingly indicate that while MSI is most beneficial, in terms of response gain, at far distances, temporal binding occurs over a smaller range of asynchronies for far stimuli. These findings highlight the intrinsic interdependency and putative asymmetrical relationship between multisensory gain and temporal binding as a function of proximo-distal space. The results are discussed in terms of distance-dependent differences in the need for spatial and temporal binding.

#239 Audiovisual integration of ON and OFF signals

Cesare Parise, Marty Banks, Marc Ernst

Unisensory information is of course processed before integration with signals from other senses. Here we investigate how the intensity of visual and auditory stimuli is represented at the integration stage. Specifically, we tested whether information about stimulus intensity is preserved, or whether signals are rectified so that only intensity changes are represented (irrespective of the polarity). To do so, we used audiovisual

stimuli that consisted either of step increments (ON stimuli) or decrements (OFF stimuli) in intensity over time. ON and OFF stimuli were paired in all possible combinations. In some pairings, the stimuli both increased or decreased in intensity. In other pairings, one increased while the other decreased. In separate conditions, participants reported (1) the modality that seemed to change first, and (2) whether the two modalities changed at the same time or not. Recently, we developed a model in which multisensory integration relies on elementary units analogous to the motion-energy units observed in insect visual systems. In its original form, the model does not rectify the signals, so an increment in intensity in one modality paired with a decrement in the other would produce an inversion of perceived temporal order, reminiscent of the "reverse phi" effect in visual motion perception. Psychophysical data showed that subjects could accurately report the temporal order of the two signals, even when the intensity in the two modalities changed in opposite directions. This suggests that before integration unisensory signals are rectified, yielding an estimate of the time of change without regard to sign. A simple model in which unisensory information is processed through biphasic filters in quadrature pair, before feeding into an energy unit, yields behavior consistent with our experimental observations. Without fitting parameters, the same model tightly predicted simultaneity perception for periodic sequences of visual and auditory stimuli with a square-wave profile.

#240 Audio-tactile speech training provides sustained benefits for perception of degraded auditory speech.

Josh Dorsi, Lawrence D. Rosenblum, Sharon Chee, Stephanie Tickemyer, Vanessa Ceja, James W. Dias

While audio-alone training can improve the perception of degraded speech, training is more effective with audio-visual speech (e.g. Bernstein, et al., 2013). What is the source of this bimodal training advantage? One explanation is that listeners must invoke learned associations between auditory and visual components of the speech signal that they acquired through their vast experience hearing and seeing speech. Alternatively, bimodal experience may simply assist listeners in attuning to the amodal invariants present in each stimulus stream. Given the frequency with which listeners are exposed to audio-visual speech, it is difficult to determine if the bimodal training advantage requires vast experience with the involved modalities. For this reason, the present study exploits a

form of bimodal speech with which most listeners have little or no experience: audio-tactile speech. The Tadoma technique involves perceivers placing a hand on a speaker's lips, jaw, and neck to feel the articulations of a talker. Prior work shows that Tadoma can enhance perception of degraded auditory speech even with no prior experience with the technique (e.g. Trielle, Vilain, & Sato, 2014). Here we find that despite subjects having no prior experience associating the modalities, training with audio-Tadoma speech improves the perception of subsequent audio-only speech, relative to audio-only training. Interestingly, gains from training with audio-Tadoma speech also appear more robust than gains from audio-only training, with audio-Tadoma listeners retaining more of their training gains one week following training.

#241 The role of endogenous modality-specific attention in multisensory integration

Ambra Ferrari, Uta Noppeney

To form a coherent representation of the environment, the brain merges signals across the senses weighted by their relative reliabilities. The extent to which attention top-down modulates multisensory integration remains unclear (Tang et al., 2016). While multisensory integration was traditionally considered to be automatic, recent evidence suggests that the sensory weights can be modulated by attention(Odegaard et al., 2016). We evaluated the role of modality-specific attention in audio-visual (AV) integration using spatial ventriloquism in an attentional cuing paradigm. Participants were presented with synchronous auditory and visual signals that were independently sampled from four different locations. In a 2 x 2 factorial design they werepre-cued to attend to the auditory or visual modality and post-cued to report the auditory or visual location. Our results demonstrate that the pre-cued attentional focus increased the weight of the attended sensory modality in AV integration as quantified by a stronger AV spatial bias. Bayesian Causal Inference modelling reveals that attention increased the reliability of the attended sensory signal. Ongoing research aims to determine the hierarchical level and neural mechanisms by which attention modulates the sensory weights in the multisensory integration process (Rohe and Noppeney, 2015).

#242 Cross-sensory prediction in ASD

Ana A. Francisco, John J. Foxe, Hans-Peter Frey, Sophie Molholm

Multisensory integration allows us to take advantage of redundant and complementary multisensory cues, and consequently form percepts that are more reliable. For instance, seeing a talker's articulatory gestures improves recognition of speech sounds. This audiovisual benefit is not restricted to speech; rather, it should be observable whenever visual information precedes and predicts the auditory input (think, for example, of someone clapping). Modulations of the auditory event-related potential (ERP) components N1 (~100 ms) and P2 (~200 ms) have been consistently implicated as indices of multisensory integration. In the general population, the auditory-evoked N1 and P2 components are attenuated and speeded up when the auditory signal is accompanied by predictive congruent visual information. The general assumption is that precedence of visual information reduces signal uncertainty and lowers the computational demands on auditory brain areas. In the present study, we aimed to determine whether the multisensory facilitatory effects described above were present in a sample of children and adolescents diagnosed with ASD. 24 typically developing and 19 ASD individuals were presented with speech and non-speech (predictive and non-predictive) multisensory stimuli, while high-density scalp electrophysiological measurements were taken.Preliminary analyses suggest that while multisensory predictive effects are present, they may be delayed in ASD.

#243 Detection and integration of auditory and visual signals: Comparing typical and high autism spectrum quotient (ASQ) performance

Benjamin A. Stettler, Mark E. McCourt

Introduction. We previously examined differences in visuospatial attention for social and non-social stimuli in neurotypical individuals with varied autistic trait expression. Here we extend our study by comparing the detection and integration of auditory (A) and visual (V) signals in participants with varied levels of autistic trait expression. Method. Participants (N = 62; 27 female) completed the adult ASQ questionnaire (range = 13-41). The task was a speeded manual response to any A or V stimulus. In multisensory trials AV stimulus onset asynchronies (SOAs) ranged from ±300 ms. Reaction times (RTs) were measured for all trials. Results. A repeated-measures ANOVA for mean RT revealed

significant main effects for both SOA [$F(3.61, 216.83) = 59.66$, $p = .001$, $\eta^2 = .50$] and Group [$F(1, 60) = 4.62$, $p = .036$, $\eta^2 = .072$], but no significant Group X SOA interaction [$F(3.61, 216.83) = .693$, $p = .583$]. Post hoc t-tests revealed that the high ASQ group had significantly faster mean reaction times at most SOAs compared to the typical ASQ group. Reaction times on AV trials for both groups were significantly faster at SOAs near 0 ms, however, violations of Miller's Inequality were not significantly different between the high and typical ASQ groups. Mean RT to the unisensory V stimulus was faster than to the unisensory A stimulus for both the typical and high ASD groups: $\bar{V}$ = 316.5 ms; $\bar{A}$ = 346.9 ms and $\bar{V}$ = 288.5 ms; $\bar{A}$ = 301.8 ms, respectively. Paired-sample t-tests confirmed that RT to unisensory V signals was significantly faster than to A signals for both typical [$t(29) = 4.05$, $p = .001$] and high [$t(31) = 2.78$, $p = .001$] ASQ groups.Conclusions. There were no significant differences in violations of Miller's inequality across high and typical ASD groups. The high ASQ group had significantly faster RTs for all stimuli. The faster RTs for the high ASQ group may indicate superior attentional preparedness, faster multisensory signal processing, or both.

#244 Audiovisual congruence of adapting stimuli facilitates visual motion aftereffect

Minsun Park, Yeseul Kim, Chai-Youn Kim

Adaptation to physical motion in a certain direction induces motion aftereffect (MAE), illusory motion perception in the opposite direction (Tootell et al., 1995). Previous studies have shown the MAE transferred between sensory modalities: between vision and audition (Jain et al., 2008) or between vision and touch (Konkle et al., 2009). However, it has not been addressed whether integration of bisensory motion information influences the strength of resulting MAE. In the current study, we investigated whether visual MAE is modulated by the direction congruence of audiovisual motion during adaptation. Random-dot kinematogram (RDK) in which a portion of dots moving leftward or rightward was presented 6 degrees below fixation. The circular aperture of RDK subtended 0.85 degrees and the dot density was 10 dots/arcmin. Auditory stimulus was created by simulating inter-aural time difference so that it was perceived as moving leftward or rightward. There were three conditions according to the audiovisual motion congruence: congruent, incongruent, and no-sound. During the initial adaptation phase, seven participants viewed RDK in a given direction for 45s. The motion coherence of RDK alternated between individual motion detection threshold and its multifold increase for

every other second. Sound was accompanied while the motion coherence was higher. During the test phase, a series of 500-ms RDKs in the direction opposite to the visual MAE was presented using an adaptive staircase procedure, which allowed us to measure motion coherence required to nullify the MAE. A 10-s top-up adaptation was interleaved with each test trial. Results showed that the motion coherence nullifying the MAE was elevated in the congruent compared to the incongruent or no-sound conditions. This was not due to the difference of gaze stability across conditions. The current findings suggest that the bisensory integration based on the audiovisual motion congruence during adaptation enhances the strength of the visual MAE. Supported by NRF-2016R1A2B4011267.

#245 Simultaneous measurements of BOLD fMRI activity in the superior temporal sulcus and behavior during perception of the McGurk effect

Johannes Rennig, Michael S. Beauchamp

Speech is the most common form of human communication and is fundamentally multisensory: observing the mouth of the talker allows us to identify otherwise ambiguous auditory information. A powerful demonstration of the multisensory nature of speech is the illusion discovered by McGurk and MacDonald (1976) in which the combination of incongruent different auditory and visual syllables evokes the percept of a completely different syllable. Recent evidence suggests that there are large interindividual differences in the McGurk effect, with some low-susceptibility subjects who never perceive the illusion and some high-susceptibility subjects who always perceive it (Basu Mallick et al., 2015). BOLD fMRI studies have demonstrated a correlation between the amplitude of responses in the superior temporal sulcus (STS) and McGurk susceptibility in both adults (Nath & Beauchamp, 2012) and children (Nath, et al., 2011). However, these studies did not require subjects to report their perception in the MR scanner and instead measured McGurk susceptibility in a separate behavioral session. In the present study, we addressed this deficiency by simultaneously measuring brain activity and behavior. Subjects viewed McGurk and control stimuli from two talkers and reported their percept with a button press. This allowed us to sort trials in which subjects perceived the illusion from trials in which they did not. Across individuals (N = 8), there was a positive correlation between each subject's degree of McGurk susceptibility and the amplitude of the response in that subject's STS. However, this

relationship was observed only for trials on which the McGurk effect was perceived (r = 0.35). In trials on which the effect was not perceived, there was no cross- subject correlation between susceptibility and amplitude of STS response (r = -0.01). A possible explanation for this finding is eye movements. Previous studies have demonstrated that subjects who are susceptible to the McGurk effect are more likely to fixate the mouth of the talker (Gurler et al., 2015). The talker's mouth movements would then be expected to evoke large responses in the STS. In contrast, subjects who are less susceptible to the effect are more likely to fixate the eyes of the talker (which do not make obligatory movements during speech production) resulting in smaller evoked responses in the STS; a similar process could occur in trials in which the illusion is or is not perceived. To test this idea, it will be necessary to record the eye movements made in response to McGurk stimuli while measuring BOLD fMRI activity.

#246 Do global or local features make an abstract shape appear more “baba” or “kiki”?

Brianna Leonardo, Hiu Mei Chow, Vivian Ciaramitaro

Cross modal processing is ubiquitous in our everyday lives and allows us to process and integrate information from our environment efficiently. In one example, the “bouba-kiki” effect, rounded shapes are associated with the pseudoword “bouba”, while spikey shapes are associated with “kiki” (Bremner et al., 2013). Interestingly, shape features, like protrusion number, size and spikiness, can be weighted differently based on culture (Chen et al., 2016), suggested to arise from differences in global/local perceptual processing style. We tested when an ambiguous shape was perceived as more “bouba” or “kiki” under conditions where global and local features matched (congruent) or did not match (incongruent). We expected that adults will focus primarily on global processing and will therefore identify shapes that were rounded globally as “bouba”, even if locally it is spiky. Adult participants, seated 60 cm from an Apple computer screen while wearing headphones, used a button box to indicate their judgment: whether the first or second sound they heard (/baba/ or /kiki/) best matched the image displayed on the screen. The global (roundedness of the overall contour) and local (roundedness of local elements forming the contour, texture, or an inner shape) properties of the image were independently manipulated to create ambiguous shapes. For example, a globally spikey shape could be locally round, by having round local ridges on the contour, being filled in with rounded texture, or containing a smaller round shape. We found that prioritization

of global contour depended on the manipulation of local features. For example, when the local element was pointy, even if the global shape was rounded, the image was perceived as “kiki”. However, local manipulation of texture and inner shape did not affect judgment of the image based on global contour, suggesting the dominance of global processing in the “bouba-kiki effect” in young adults.

#247 Multisensory self-motion perception in healthy older and younger adults

Robert Ramkhalawansingh, John Butler, Jennifer Campos†

† presenting author

Everyday behaviours like walking and driving require reliable self-motion percepts. Self-motion perception involves the integration of multiple sensory inputs including visual, vestibular, proprioceptive and auditory cues. Previous evidence has shown that younger adults optimally integrate multisensory cues to self-motion (e.g. visual + vestibular inputs), however, little is known about whether multisensory self-motion perception changes with older age. Notably, compared to younger adults, older adults are more susceptible to gait and posture disturbances when presented with unreliable or conflicting visual or vestibular cues and are more negatively affected by reduced sensory conditions during driving. However, to date, few studies have used precise psychophysical techniques to quantify the relative weights that older adults assign to visual and vestibular cues and whether (and under what circumstances) these cues are optimally integrated. Thus, we used a motion simulator and immersive virtual reality display to present a two-alternative forced choice heading estimation task in which older adults (65+) and younger adults (18-35) were asked to judge which of two movements was "more to the right". The movements consisted of either vestibular cues alone (passive movement in the dark), visual cues alone (optic flow), or both cues combined. In the combined condition, visual-vestibular cues were either congruent, or incongruent with small (5Â°) or large (20Â°) spatial conflicts introduced. In the unisensory conditions older adults demonstrated less reliable visual estimates than younger adults, but were comparable in their vestibular estimates. Both groups exhibited near optimal integration during the combined, congruent condition and during small spatial conflicts. However, for large spatial conflicts, older adults did not appear to use reliability-based weighting, with a bias towards the less reliable visual estimates. These results suggest that older adults

may be more vulnerable to performance declines under discrepant sensory conditions, with potential negative consequences to tasks such as walking and driving.

#248 Auditory cortical projections to the superior colliculus are altered by early-onset hearing loss in the cat

Blake E. Butler, Julia K. Sunstrum, Stephen G. Lomber

The onset of hearing loss initiates structural and functional changes in the brain that have been measured anatomically, electrophysiologically and behaviorally. Much of the focus on anatomical change has been placed on ascending thalamocortical projections, and on connectivity within the auditory cortex and between sensory cortices. However, sensory cortices also send descending projections to midbrain structures including the superior colliculi, which are central to integrating multisensory representations of stimuli in the environment and guiding orienting behaviours based on these cues. We recently provided the first comprehensive quantitative description of sensory and motor corticotectal projections within a single species (Butler, Chabot, and Lomber 2016). As expected, visual cortical fields dominate these projections; however, substantial projections were observed to arise from multisensory areas, including the auditory field of the anterior ectosylvian sulcus (fAES). Here, we seek to quantify the ways in which these patterns of whole-brain projections to the superior colliculi are altered by early-onset hearing loss. The retrograde neuronal tracer BDA was injected into the superior colliculus of cats ototoxically deafened shortly after birth, around the time of hearing onset. Coronal sections were taken at regular intervals and neurons showing a positive retrograde labeling were counted, and assigned to functional cortical areas according to published criteria. The relative proportions of labelled cells arising from each sensory cortical region were compared, and while the overall proportion of labelled cells in auditory cortex was similar to that of normal hearing animals, the field-specific pattern of projections was dramatically altered. These changes will be discussed in the context of plasticity following sensory loss, with focus on the development of multisensory cortex.Supported by the Natural Sciences and Engineering Research Council of Canada, the Canadian Institutes of Health Research and Canada Foundation for Innovation.

#249 Investigating the utility of phoneme-related potentials (PRPs) to study the development of audiovisual speech processing

Aida M. Davila, Michael J. Crosse, Sophie Molholm

Perception is aided by the ability to integrate multisensory information from the environment. Multisensory integration is especially notable when there is ambiguity in a unisensory modality. For instance, previous studies have shown that under noisy circumstances speech perception is substantially enhanced by the simultaneous presentation of auditory and visual information (Ross et al., 2006). Although the benefits of audiovisual (AV) integration in speech perception have been demonstrated in behavioral experiments, the underlying neural mechanisms remain under investigation. Electrophysiological (EEG) studies offer insight into the neural dynamics of multisensory integration. However, the AV stimuli used in such experiments typically consist of isolated events presented repeatedly. Such stimuli may not fully engage the vast cortical networks involved in processing of continuous speech, offering only limited insight into the full extent of multisensory enhancement of speech processing. A recent EEG study by Khalighinejad et al. (2016) demonstrated that phoneme-related potentials (PRPs) can be extracted using continuous speech by time-locking neural responses to individual phonemes. Here, we adapted this approach and extracted PRPs to speech presented in a multisensory context. High-density EEG was recorded while children (n = 8) and adults (n = 8) were presented with continuous unisensory (A, V) and multisensory (AV) speech at different signal-to-noise ratios (2 dB, âˆ’6 dB, âˆ’14 dB). Stimuli were phonetically transcribed and the timing of each phoneme was used to extract the corresponding PRP from the neural response. Preliminary data suggest that auditory-evoked PRPs in children differ as a function of manner-of-articulation, and that visual speech cues differentially influence the temporal dynamics of each PRP. This novel approach offers insights into how visual information enhances speech perception at a phonetic level, providing an ecologically relevant way to study the developmental course of multisensory speech processing in children and clinical populations.

#250 Reconciling discrepant codes of visual and auditory space

Valeria C. Caruso, Marc A. Sommer, Jennifer M. Groh

We experience space as a unitary/coherent whole, regardless of which sense(s) are involved in detecting the stimuli that make up the scene. However, spatial information acquired through different senses is known to be represented in the brain in different formats. In particular, visual location is encoded in maps but auditory location is encoded in meters or rate codes in areas such as primary sensory cortices and the primate superior colliculus (SC), a motor region that controls eye movements directed towards visual and auditory targets. The discrepancy in coding format across sensory modalities raises the question of how and where such differences get resolved. Here, we quantitatively compare the visual and auditory representations in three brain areas: the SC, the frontal eye field (FEF), and the lateral and medial intraparietal cortex (LIP/MIP). All of these areas contain both visual and auditory signals and are thought to contribute to guiding saccadic eye movements to visual and auditory targets. We investigated single cell and population coding of visual and auditory target locations during a saccade task using the same experimental conditions in all three areas. We found that single cell tuning curves for visual and auditory stimuli were broad and more similar to each other in the cortical areas compared to the SC. However, the degree of similarity between visual and auditory tuning curves was not predictive of the population encoding when evaluated with principle components analysis. Whereas the SC and FEF encoded space almost independently of modality at the population level, the LIP/MIP encoded visual and auditory space in two largely distinct populations, compressing the auditory space with respect to the visual space. These results suggest an alternative method of evaluating coding format beyond maps and meters and their associated closed vs. open fields. The different results suggest different fidelity of spatial representations between areas, possibly subserving different roles, such as multisensory integration vs. precise movement execution.

Poster Abstracts

#301 Which sounds mean pointed? Examining auditory-visual cross-modal correspondences using representational similarity analysis

Sara M. List, Kelly R. McCormick, Krish Sathian, Lynne C. Nygaard

Humans consistently indicate correspondences between the sounds in a word (e.g. 'loh-moh') and the visual physical shape of objects (e.g. blob). This phenomenon is an example of a sound symbolic cross-modal correspondence. Multiple other examples of cross-modal correspondences between auditory and visual features of objects exist (e.g. low pitch and large size vs. high pitch and small size). Others have investigated auditory-visual cross-modal correspondences and shown that modulating the physical dimensions that define them can influence multisensory integration. The boundaries in auditory and visual perceptual space that evoke cross-modal correspondences remain unclear, particularly for sound symbolic cross-modal correspondences. This study attempts to pinpoint the boundaries of multiple acoustic properties that evoke specific sound-to-meaning mappings with two opposite visual physical traits, rounded and pointed. An analysis was conducted of associations between these visual traits with phonetic and acoustic attributes of systematically varied nonsense words. Nonsense words containing certain phonetic segments were consistently rated as either pointed or rounded across tasks. This finding is consistent with previous studies in which researchers examined sound symbolic cross-modal correspondences at the level of phonetic categories. However, these analyses are limited by the constraint of predefined linguistic categories that may not fully represent the acoustic traits driving these sound-to-meaning mappings. A data-driven approach with representational similarity analysis (RSA) was thus implemented to expand upon previous research, to minimize the potential bias inherent in the categorization of nonsense words, and to explore in greater depth the specific acoustic properties that influenced listeners' judgments of correspondences to visual shape attributes. RSA revealed the existence of patterns in the correlations between ratings of a physical property that can be assessed visually and the complex sound structure of nonsense words. This research provides insights into the acoustic features that evoke specific interpretations of physical meaning in natural language.

Poster Abstracts

#302 Representation of sound symbolism in the infant brain: Investigation using the near-infrared spectroscopy

Jiale Yang, Michiko Asano, So Kanazawa, Masami K. Yamaguchi, Mutsumi Imai

Although the relation between word sound and meaning is largely arbitrary, care takers are known to use sound symbolic words (i.e., words that evoke an idea in sound) frequently to infants and toddlers. In our previous study using fMRI in adults, activation of the right posterior superior temporal sulcus (rSTS), which is considered to play a key role in processing environmental sounds, was identified when processing sound symbolic words (Kanero et al., 2014), suggesting that sound symbolic words are processed as if they were environmental sounds. The iconic bodily experience in processing sound symbolism may bootstrap infants into less iconic symbols in conventional language (Asano et al., 2015; Imai & Kita, 2014). However, how sound symbolic experience is processed in infants' brain, especially in terms of its loci, remains unknown.In the present study, we investigated the brain response in 11-month-olds when word sounds and their visual referents were matched/mismatched, using near-infrared spectroscopy (NIRS). Two types of stimuli were used: a visual stimulus (e.g., a round shape) followed by an auditory stimulus that either sound-symbolically matched (“moma”) or mismatched (“kipi”) the shape. The hemodynamic responses in the match and the mismatch condition were contrasted against those during the baseline where a neutral shape was followed by a white noise.In the match condition, a significant increase in the hemodynamic responses was found in the channels around T4 positions in the International 10-20 system, whose anatomical loci were estimated to correspond to the right STS. In contrast, no such increase was observed in the mismatch condition. These findings suggest that preverbal infants have biological basis to detect cross-modal correspondences between word sounds and visual referents in the same way as adults do.

#303 Modality-specific and general neural mechanisms underlying momentary lapses and enhancement of attention

Wen Su, Huan Wang, Jiedan Chen, Jing Wang, Shiyong Chen, Yuqian Yang, Yi Yang, Qi Chen

Momentary lapses in attention can disrupt goal-directed behavior numerous times each day. One of the most direct finding of the past decade has been the observation that attentional lapses derived from the reduced early activity in brain regions associated with control of attention and the increased default mode network activity (Weissman, Roberts, Visscher, & Woldorff, 2006). Although numerous studies investigated this phenomenon, it remains unknown whether there was any difference of attentional lapses between auditory and visual modality. In this study, we asked 16 participants to make auditory and visual detection responses while we recorded their response by using functional magnetic resonance imaging (fMRI). We sought to identify pre-stimulus and post-stimulus neural signals that were associated with auditory and visual lapses on each trial. Behaviorally, there was no significant difference between auditory and visual lapses. At the neural level, auditory lapses were associated with increased pre-stimulus activity in bilateral superior temporal gyrus, the supplementary motor area and the precuneus, and increased post-stimulus activity in the superior parietal cortex. In contrast, visual lapses were associated with increased pre-stimulus activity in the default mode network (i.e., including posterior cingulate cortex and medial prefrontal cortex), and increased post-stimulus activity in the default mode network. In addition, enhancement of attention of two modalities was associated with visual and parietal regions. Taken together, these results revealed the modality-specific and general neural mechanisms underlying momentary lapses and enhancement of attention.

#304 Semantics in the multisensory brain: Insights from electrical neuroimaging

Nora Turoman, Ruxandra Tivadar, Micah M. Murray*, Pawel J. Matusz*

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The environment is inherently multisensory. Brain representations of objects are de facto also multisensory. This benefits everyday functions such as speech comprehension and search, where performance is typically enhanced by semantically congruent contexts.

However, the scant studies on multisensory semantic congruence often do not control for influences of simultaneity detection or the task-relevance of multisensory simultaneity and/or semantic congruence. This notwithstanding, there is evidence that semantic congruence can impact multisensory stimulus processing largely independently of top-down attention. Specifically, memory can benefit from prior exposure to semantically congruent multisensory contexts. What remains unresolved are the mechanisms that orchestrate such benefits between stimulus encoding and later retrieval. To this end, healthy adults performed a continuous “old/new” task involving sounds of naturalistic objects while 64-channel EEG was recorded. On initial presentations, each sound was accompanied by a semantically congruent (AVc) or meaningless drawing (AVm) or appeared alone (A). Repeated presentations were exclusively sounds. Categorising a sound as “new” benefited both from multisensory simultaneity as well as semantic congruence. However, only the benefit of semantic congruence translated into improved recognition for repeated presentations of sounds. ERP analyses revealed topographic differences, and by extension network configuration differences, between AVc and AVm, at 102-132ms and 184-254ms. Over this latter period (208-262ms) one topographic map predominated responses to AVc, while multiple maps similarly characterised responses to AVm. Responses to AVc were likewise stronger and peaked earlier than those to AVm (224- 268ms). Brain networks responsive to multisensory semantic congruence are thus distinct from those responsive to multisensory simultaneity. Moreover, memory benefits from task-irrelevant semantically congruent multisensory contexts are accompanied by predominance of activity of one brain network >200ms post-stimulus onset. These results support recent theoretical frameworks characterising the interplay between attention and memory by highlighting their role in orchestrating multisensory processes (ten Oever et al. 2016 EBR).

#305 Multisensory interactions in frequency sweep perception

Lexi E. Crommett, Deeksha Madala, Jeffrey M. Yau

Naturally occurring signals in audition and touch are complex. Frequency sweeps, or monotonic changes in frequency, are one aspect of this complexity. We have previously shown that audition and touch interact in the frequency domain for simple sinusoids. Here we tested the hypothesis that audition and touch interact in processing frequency sweeps. In a series of psychophysical experiments, participants performed sweep

discrimination tasks in which they judged whether a tactile frequency sweep was increasing or decreasing in frequency. On most trials, auditory frequency sweeps co-occurred with the tactile sweeps and subjects were instructed to ignore the distractor sounds. We manipulated the relationship between the sweep directions of the sounds and vibrations. We found that auditory frequency sweeps systematically biased tactile sweep perception in a direction specific manner. In control experiments we found that tactile sweep perception was unaffected by auditory sweep distractors when the sounds occurred in a different frequency range or when they changed in intensity rather than frequency. Thus, audition and touch interact in frequency sweep perception in a frequency- and feature-specific manner. We reproduced the perceptual biases induced by the auditory distractors using a simple network model in which sweep magnitude and direction are decoded from a population of neurons that receives auditory and tactile sweep inputs. Our results demonstrate that audio-tactile interactions are not constrained to the processing of simple sinusoids. This implies that multisensory interactions in the temporal domain occur across multiple levels of sensory processing hierarchies.

#306 Odor concentration change detectors in the olfactory bulb

Ana Parabucki, Alexander Bizer, Genela Morris, Matthew C. Smear, Roman Shusterman†

† presenting author

Olfactory navigation requires comparing of, odor concentration across samples distributed in space and time. One potential strategy of odor source localization is sequential (temporal) comparison: the animal chooses direction in the olfactory surroundings by detecting concentration changes in time (ΔCt) across consecutive inhalations. To study the neural processing of ΔCt, we developed an odor delivery system that allows rapid switching and stabilization of different concentrations of an odor, such that concentration can be changed on each sniff. We monitored activity of mitral/tufted (M/T) cells in the olfactory bulb of mice in response to prolonged concentration presentations and to stimuli that flicker between concentrations from sniff to sniff. We have found that a subset of mitral/tufted (M/T) cells in the olfactory bulb explicitly represent ΔCt. These concentration change detectors are direction selective: some respond to positive ΔCt, while others represent negative ΔCt. This change detection enhances the contrast between different concentrations and the magnitude of contrast

enhancement scales with the size of the concentration step. Further, ΔCt can be read out from the total spike count per sniff, unlike odor identity and intensity, which are represented by fast temporal spike patterns. Our results demonstrate that a subset of M/T cells explicitly represents ΔCt, providing a signal that may instruct navigational decisions in downstream olfactory circuits.

#307 Relationships between crossmodal correspondences and autistic traits in typically developing adults

Souta Hidaka, Ayako Yaguchi

The recent viewpoint on autism spectrum disorders (ASD) suggests that ASD-like characteristics, such as social and behavioral deficits, are not unique to people with an ASD diagnosis, but they are regarded as common properties among the general population. People with ASD have also been reported to have sensory irregularities, including crossmodal perception. Crossmodal correspondences are a phenomenon in which a specific relationship of arbitrary crossmodal sensations affects behavioral performance. For example, the presentation of a louder sound induces faster responses to a brighter stimulus than a darker one. Crossmodal correspondences are considered to be established by associative learning, but learning cues are assumed to be different among the types of correspondences. The current study investigated the relationships between the magnitude of the crossmodal correspondences and the degrees of ASD traits using the Autism-Spectrum Quotient with 65 non-diagnosed adults. We found that people with lower ASD traits value showed a stronger correspondence effect for the brightness-loudness pair, which is assumed to be governed by the correspondence cue of similarity in neural/perceptual magnitude. Further, those with lower ASD traits showed a stronger correspondence effect for the visual location-pitch pair (i.e., higher location-higher pitch), which is considered to be governed by the correspondence cue of conceptual or linguistic similarities. For the visual size-pitch pair (i.e., smaller object-higher pitch) which is assumed to be acquired by statistical learning, a stronger ASD trait for detailed attention was related to a stronger magnitude of correspondence. These results demonstrated that there are unique relationships between crossmodal correspondences and ASD traits, indicating that ASD traits differently involves in the manner of sensory associative learning.

#308 Two mechanisms for shifts in perceived limb position in the mirror box illusion

Yuqi Liu, Jared Medina

When information from vision and proprioception regarding hand position are dissociated, individuals often report their hand to be closer to the visual estimate (proprioceptive shift). While current models can predict the final estimate, they do not formalize changes in proprioceptive shift over time. Studies of the rubber hand illusion found that proprioceptive shift gradually increased over relatively long intervals (every 1 minute) at the group level. However, audiovisual integration studies showed that individuals perceived either the unimodal percept or final integrated percept, rarely experiencing intermediate percepts. We used the mirror box illusion to investigate if perceived hand position gradually shifts and/or abruptly switches during multisensory integration. Participants made synchronous bimanual movements with the right hand placed at 0" in front of the mirror and the left hand 6" behind the mirror, dissociating visually-defined and proprioceptively-defined unseen hand position. In each 60 second trial, participants reported their perceived unseen hand position every 5 seconds. For each individual trial, we calculated the ratio of maximum step (i.e. the greatest change from t to t+5 seconds in a trial) to the largest proprioceptive shift over the entire trial. The frequency distribution of the ratio was bimodal, indicating two potential mechanisms. In some trials, perceived limb position gradually shifted over the course of the trial. However, in other trials, perceived hand position shifted immediately to the visually-defined position. Consistent results were found in Experiment 2 in which participants spontaneously responded whenever they felt proprioceptive shift, indicating results in Experiment 1 were not artifacts of frequent passive responses. Overall, our findings indicate that unimodal inputs are integrated via two mechanisms during multisensory integration of the body, either gradually shifting over time or immediately jumping to the final percept.

#309 Multisensory effects in natural audiovisual speech processing are reflected in EEG predictions

Aisling E. O'Sullivan, Michael J. Crosse, Edmund C. Lalor

Our ability tointegrate multiple sensory streamsunderpins our perception of the world around us. For example, in the context of speech perception, integrating auditory (A) and

visual (V) information can greatly benefit comprehension, especially in challenging listening environments. However, the neural mechanisms underlying this integration are still not well understood, especially in the context of natural, continuous speech. Recent work has sought to address this issue by “decoding" stimulus features from EEG signals of subjects presented with unisensory (A and V) and multisensory (AV) speech. This approach has revealed multisensory effects in the fidelity with which EEG tracks the dynamics of congruent audiovisual speech (Crosse et al., 2015). Furthermore, these effects have been shown to be more pronounced in challenging listening conditions (Crosse et al., 2016). One limitation of this approach however is that it relies on a mapping between the EEG signal and the acoustic envelope of the presented speech - a very impoverished measure of the speech signal. As such, it can be difficult to mechanistically interpret neural signatures of multisensory integration based on this measure. One way in which this interpretation could be made easier would be to use an approach based on forward-encoding models. This would allow mapping of more specific representations of speech such as its spectrogram or phonemes to the EEG dynamics, which would enable more fine-grained interpretation of the hierarchical processing of audiovisual speech. However it is unclear whether or not forward encoding analysis has the sensitivity to pick up on multisensory effects in the context of natural speech. Here, using the speech envelope as a first attempt, we demonstrate that forward modeling of EEG can index nonlinear multisensory interactions in the context of natural audiovisual speech. This work paves the way towards the use of a broader variety of forward encoding models to thoroughly probe the nature (e.g., neural generators, time course and hierarchical stages) of these multisensory interactions.

#310 State-dependent influences of somatosensory cortex on audition

Silvia Convento, Md. Shoaibur Rahman, Jeffrey M. Yau

Audition and touch interact in the perception of frequency information. TheÂ-se perceptual interactions may arise from shared neural representations distributed over cortical networks that support both audition and touch. The extent to which primary sensory areas, which are traditionally considered to be dedicated to specific senses, contribute to common neural representations is unclear. Here we tested the hypothesis that the somatosensory cortex interacts with a distributed cortical network that supports frequency processing for multiple sensory modalities when attention is deployed to

vibration frequency. We manipulated somatosensory cortex activity with transcranial magnetic stimulation (TMS) while participants performed auditory, tactile, or crossmodal frequency judgments. Based on our hypothesis, we predicted that perturbations induced by TMS over somatosensory cortex would propagate through the distributed frequency-processing network to disrupt auditory frequency perception only when attention was simultaneously deployed over touch and audition. We found that TMS of somatosensory cortex impairs auditory frequency discrimination performance only during test blocks in which participants were forced to attend to both sensory modalities. Moreover, these attention-mediated TMS effects were abolished when TMS was applied over visual cortex and when participants discriminated stimulus intensity rather than frequency. Our results clearly demonstrate that the manipulation of somatosensory cortex activity impairs auditory frequency perception during specific behavioral states. Auditory and tactile frequency information may be represented in the same state-dependent cortical network when attention is simultaneously directed to the frequency of sounds and vibrations.

#311 Crossmodal correspondences between audition and vision in children

Luigi F. Cuturi, Alessia Tonelli† , Giulia Cappagli, Monica Gori†

† presenting author

Crossmodal correspondences are interesting phenomena that refer to multisensory association between sensory features of different nature. An example of such correspondence is the association between auditory pitch and visually defined object's size. Previous studies have shown that low and high pitch audio stimuli can induce shifts in visually perceived objects' size: while the first generally increases perceived object's size, the second decreases it. It can be argued that such crossmodal association is mostly based on experience (e.g. co-occurrence of high pitch sounds and impact between small rather than large objects), although not much is known about how this association emerges during the development. In order to fill this gap in the literature, we tested 71 children ranged in age from 6 to 11 years. After listening to a sound, subjects were asked to draw a circle “as big as the sound was". Auditory stimuli were pure tones of different pitch levels (250, 500, 1000, 2000, 5000 Hz) and were generated with one loudspeaker positioned in front of the subject. Responses were taken with a touch screen monitor positioned in front of the subject. As a control, we asked participants to

rate from 1 to 10 the size of drawn shape (from very small to very large) after each drawing. Results show that children of every age associate large drawings with low pitch and small drawings with high pitch sounds. Interestingly, the younger the child, the greater is the discrepancy between responses for low and high pitch stimuli. Moreover, the reported numerical rate correlates with the size of the drawn shape. These results provide a better understanding of multisensory processes subtending size perception across different developmental stages and suggest that sensory modalities other than visual can be used in learning size comparison across development.

#312 Reduced tactile modulation of visual event perception during development

Yi-Chuan Chen, Terri L. Lewis, David I. Shore, Daphne Maurer

We examined developmental changes in the interactions between vision and touch by measuring visual fission and fusion illusions induced by taps. The fission illusion refers to a single flash perceived as two flashes when paired with two taps, whereas the fusion illusion refers to two flashes perceived as one when paired with a single tap. Right-handed children (7, 9, and 11 years of age) and adults were tested. One or two flashes were presented either in the center or 10Â° in the periphery (equally often on the left or right) on a computer monitor, while zero, one, or two taps were presented on the right index finger. Participants were instructed to report the number of perceived flashes, while ignoring the taps. Children aged 7 and 9 years reported both illusions more often than adults (ps = .005). Across age groups, the fission illusion was larger when the flash was presented in the periphery than in the center (p = .005), whereas the opposite was true for the fusion illusion (p = .001). Further analyses, based on signal detection theory, demonstrated lower sensitivity (d') for children than adults when discriminating one versus two flashes (ps = .001). The larger fusion illusion in children was also associated with a criterion shift (ps = .05). Regarding the center-periphery differences, only the larger fission illusion in the periphery was attributable to lower sensitivity in the periphery (p = .001), and both fission and fusion illusions were associated with a criterion shift (ps = .01). These results demonstrate an age-related decrease in the influence of touch on vision. The signal detection results also suggest that the fission illusion is better than the fusion illusion as a measure to examine the perceptual development of visuotactile integration.

#313 Chronic pain reduction with a multisensory †˜out of body†™ illusion

Jane E. Aspell, James Pamment

Chronic pain is a growing societal concern that warrants scientific investigation, especially given the ineffectiveness of many treatments. Given evidence that pain experience relies on multisensory integration, there have been some recent attempts at using body ownership illusions for reducing acute pain. In the present study, we investigated whether patients' experience of chronic pain could be reduced by full body illusions (FBIs) that cause participants to spatially dissociate from their own body and identify with a 'virtual' body. Participants (n=18) with chronic pain conditions (including sciatica, osteoarthritis, fibromyalgia, muscular pain, IBS and back pain) viewed their own virtual bodies via a video camera and head-mounted display. In the 'back-stroking FBI', their backs were stroked with a stick while they viewed synchronous or asynchronous stroking on the virtual body, and in the 'front-stroking FBI', they were stroked near their collar-bone while viewing the stick approach their field of view in a synchronous or asynchronous fashion. Each condition lasted for two minutes. Illusion strength and pain intensity were measured with self-report questionnaires. We found that full body illusions were experienced by patients with chronic pain and further, that pain intensity was reduced by an average of 37% after illusion (synchronous) conditions. The degree of pain reduction was positively correlated with illusion strength in the synchronous back stroking condition. These findings add support to theories that high-level multisensory body representations can interact with homeostatic regulation and pain perception. These data also demonstrate the potential of such illusions for the management of chronic pain.

#314 Seeing what you will feel: On the relationship between sensory priors and movement kinematics

Georgiana Juravle, Francisco Colino, Gordon Binsted, Alessandro Farnè

There is ample evidence highlighting the various stages of goal-directed movement influence on perceptual processing. For instance, with respect to tactile perception, research has delineated attentional beneficial effects during movement preparation, but consistent deterioration during movement execution. Here, we set to investigate the reverse influence, that is, whether and how the visually-conveyed tactile qualities of an

object to be grasped affect the kinematics of the executed movement. To achieve this purpose, each trial we presented our participants with a cylindrical object and instructed them to prepare to grasp it. Vision was then occluded for a variable delay during which the object could be replaced (or not), depending on the condition. The return of vision was the go signal for the movement. Participants reached for, grasped, and lifted the object off the table. We used two objects, a smooth cylinder and a carved one. Because we were interested in how sensory priors might affect the movement profile, we manipulated the probability of the object being the same at the time of the go signal (by blocks: 100%, 50%, and 80%). In an additional block (80% +), a third unexpected 'spiky' object could be presented (only twice). Results indicate that participants' reaction times to initiate the reach-to-grasp movement were affected by the type of object they are presented with, with RTs being faster for the carved object. The carved object was also characterized by an earlier grip aperture peak, across all probabilities tested here. Interestingly, when exposed to the unexpected spiky object, participants' movement trajectory was significantly altered, as compared to the conditions where no unexpected sensory event was delivered. Our findings shed new light onto the influence exerted by perceptual processing on goal-directed movement control.

#315 A meta-analysis of the Colavita effect: Do visual stimuli overshadow auditory targets in children and adults

Rebecca Hirst, Lucy Cragg, Harriet Allen

It has been reported that when adults are presented with an auditory stimulus at the same time as a visual stimulus, they respond as though only the visual stimulus was presented (“Colavita Effect”). This has been proposed to be due to visual dominance over audition or due to asymmetric facilitation and inhibition between the two modalities. These asymmetries or imbalances have been suggested to vary with age however, such that whilst adults manifest visual dominance, young children manifest auditory dominance.Here we provide the first quantitative synthesis of studies exploring this “Colavita Effect”. We converged data from 66 experiments across 24 studies exploring the effect in adults and children. We also implement a mixed-meta regression model in order to assess whether the Colavita effect is influenced by methodological differences between studies or the age group being tested. Variables included were; the ratio of visual, auditory and bimodal stimuli, the number of response keys, if there were simple

(e.g. tones, lights) or complex (e.g. pictures, natural sounds) stimuli, the presence of attentional biases towards one or other modality (whether by instruction, stimulus set, or task), if there was congruency between the auditory and visual stimuli, and age group (children or adults). In studies exploring the Colavita effect in adults, a medium, approaching large, effect size was evident. However studies exploring the Colavita effect in children yielded a small, reverse, Colavita effect. None of the methodological factors influenced the effect. These findings suggest an asymmetry between hearing and vision, as measured by the Colavita effect. The effect is robust to task differences. However, whilst visual stimuli do overshadow auditory targets in adults, auditory stimuli may take precedence in childhood.

#316 The relation between multisensory integration, communication and autism symptomatology: A meta-analysis

Jacob I. Feldman, Tiffany G. Woynaroski

Differences in sensory perception are now considered diagnostically significant for autism spectrum disorder (ASD). Researchers have begun to describe how children with ASD differ from their typically developing peers on measures of multisensory integration [MSI]; three non-systematic reviews of this literature have been published. None of the prior reviews, however, have aggregated results in a meta-analysis or synthesized the evidence on correlations between MSI and autism symptomatology. The purpose of the present study was to conduct a systematic review and meta-analysis of the literature on MSI, specifically audiovisual integration, in children with ASD to evaluate the relations between MSI and (a) measures of communication and (b) autism symptom severity. To identify eligible studies, a comprehensive search strategy was devised using the ProQuest search engine and the PubMed database. Eligibility criteria for studies were (a) confirmation of ASD diagnosis via standardized measure and (b) inclusion of behavioral or neural measure of audiovisual integration. Grey literature searches are ongoing. Data were extracted from all studies that reported a correlation coefficient (r) of interest; Fisher transformations were then used to transform rs to zs (for variance stabilization). Effect sizes were analyzed using a random effects model. The electronic search yielded 451 records (381 unique). Preliminary analyses included 8 studies reported in 11 records (8 peer-reviewed articles, 3 dissertations). Five studies reported correlations between MSI and language/communication, resulting in an overall correlation of z =

0.45, 95% CI [0.20, 0.70]. Six studies reported correlations between MSI and autism symptom severity, resulting in an overall correlation of z = †‘ 0.31, 95% CI [†‘ 0.51, †‘ 0.10]. Final analyses will be presented. Greater MSI is significantly associated with better language and communication skill and lower autism symptom severity in children with ASD. Limitations and directions for future research will be discussed.

#317 Temporal facilitation of audiovisual speech processing in young children with Autism Spectrum Disorder

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† presenting author

Explaining individual differences in language understanding and use of young children with autism spectrum disorder (ASD) is a top priority of research because language has been repeatedly linked with long-term outcomes in this population. Temporal facilitation (the gain in speech processing speed that is associated with having access to visual speech cues) may account for variability in language understanding and use across children with ASD. Previous work indicates that older, relatively high functioning children with ASD are highly variable in their ability to perceive visual speech cues. Children with ASD who do not use visual speech cues may process speech more slowly, and slow speech processing may underlie impairments in understanding language, leading to delays in using language. This project will evaluate the theoretical association between temporal facilitation and language in a sample of children with ASD who are younger and who represent a broader range of cognitive and functioning levels than have previously been studied. Our task is a direct neural measure that is low in demand, but that has the temporal resolution needed to capture the speed of the neural response to rapid audiovisual speech input - event-related potentials (ERPs). We hypothesize that young children with ASD will show less temporal facilitation on average relative to their typically developing peers, but that there will be a wide range of individual differences in the extent to which visual cues “speed up" speech processing across children with ASD. We anticipate that the degree of temporal facilitation experienced (a) may be explained by gaze patterns to audiovisual speech and (b) will positively correlate with measures of language understanding and use. If our hypotheses are born out, this work will have

identified an impediment to language development in children with ASD that independent evidence suggests is malleable and therefore potentially remediable.

#318 Effect of prior knowledge on localization of tactile stimulation

Stephanie Badde, Michael S. Landy

The ability to localize vibrotactile stimuli varies with stimulus strength and location. We tested whether humans incorporate stimulus properties when localizing tactile stimuli either relative to a visual reference or via pointing responses executed blind. On each trial, one of five horizontally aligned stimulators buzzed the back of the dominant hand. Stimulators were hidden from view. Visual condition: Participants fixated a mark horizontally centered above the dominant hand on the occluder, vertically aligned with the stimulators. After each tactile stimulus a “ruler” (row of colored patterns) was projected onto the occluder. Participants indicated the perceived location of the stimulus by selecting a pattern. Pointing condition: Participants fixated the mark between blocks and maintained fixation with closed eyes. They indicated the location of the stimulus using a stylus on a touchpad mounted on the occluder. We are interested in localization bias, possibly based on the set of stimulated locations, so no feedback was given. In separate sessions, the stimulator locations were distributed around the center, left or right side of the hand. In each session, the spatial distribution of stimulation was learned in two practice blocks. Two strengths of vibrotactile stimulation were used: 2x and 3.5x participants' detection thresholds for each stimulator. To estimate participants' localization uncertainty, they completed a 2IFC location-comparison task. In both conditions, participants showed a localization bias towards the center of the locations tested in the session. The bias was stronger for the weaker stimulus strength. However, this bias was weaker than optimal (Bayesian). Additional bias toward the center of the hand (i.e., the fixation mark) persisted. The best-fitting model combined a prior based on the distribution of stimuli with a likelihood whose variance depended on stimulus strength and location on the hand as well as a bias towards center of the hand.
MSL: NIH EY08266. SB: DFG BA5600/1-1

#319 Interactions between auditory elevation, auditory pitch and visual elevation during multisensory perception

Yaseen Jamal, Simon Lacey, Lynne Nygaard, K. Sathian

Cross-modal correspondences are apparently arbitrary associations between sensory properties in different modalities and are almost universally experienced. For example, people consistently match high and low auditory pitch with high and low visuo-spatial elevation, respectively. These correspondences impact veridical judgments of multisensory phenomena and signify an essential mechanism underlying perceptual integration. The present study explored the well-known crossmodal correspondence between auditory pitch and visuo-spatial elevation. We asked whether this robust association interacts with auditory elevation, given that high and low auditory pitch also correspond with high and low elevation of the sound source, respectively. To address this question, we presented simultaneous audiovisual stimuli during a 2AFC speeded classification experiment where participants attended to auditory pitch, auditory elevation, or visual elevation while the auditory cues (high or low frequency bursts of white noise) and the visual cue (a 4cm white circle presented against a black background) each occurred at either high or low spatial locations. These audiovisual stimuli represented three correspondence types (cross-modal featural: auditory pitch/visual elevation; within-modal featural: auditory pitch/auditory elevation; cross-modal spatial: auditory elevation/visual elevation) and were congruent (high/high or low/low) or incongruent (high/low or low/high) with respect to each. We measured the effects of congruency on response times, and then tested for modulatory interactions between the three correspondence types. We did not find any interactions when participants discriminated visual elevation. However, we observed a modulation of the cross-modal featural correspondence by the within-modal featural correspondence during discrimination of auditory elevation and auditory pitch, and the reverse modulation during discrimination of auditory pitch only. Further, there were complex interactions between the cross-modal spatial correspondence and the other two correspondence types. We conclude that the cross-modal correspondence between pitch and visual elevation interacts strongly with auditory elevation.

#320 Visual experience and spatial reference frames for sound localization

S. Finocchietti, E. A. Cooper, M. Gori

Individuals with congenital blindness (CB) are superior to sighted individuals in some auditory tasks. However, this is not the case for vertical sound localization, for which it is thought that combined visual-auditory experience is essential. We recently found a deficit on auditory localization of the end-point of dynamic sounds in individuals with CB, as compared to sighted controls. The errors made by individuals with CB are highly precise, with a systematic bias: sound end-points below the nose are compressed upwards. Here, we investigated the frame of reference of this bias and the role that prior assumptions about sound sources might play. Twenty participants (10 CB, and 10 healthy age-matched blindfolded controls) were asked to reproduce a hand pointing task toward a moving sound and detect the final location. To disambiguate allocentric and egocentric reference frames, the test was repeated twice: once with the head upright, and once with the head tilted (35 degrees leftward or rightward). Individuals with CB showed a similar pattern of spatial bias in world coordinates for both the head upright and tilted conditions, suggesting an allocentric frame of reference. In contrast, controls were unbiased with the head upright, but showed a compression towards the rotated axis when the head was tilted. These results suggest that the two groups employ a different frame of reference when performing sound localization. We discuss the results in terms of a Bayesian framework and the possible role of prior assumptions about sound sources based on visual and auditory experience. Acknowledgments: This research has been partially supported by the European ABBI project (FP7-ICT 611452).

#321 Pre-stimulus influences on auditory perception and decision-making in healthy ageing

Steven W. McNair, Stephanie J. Kayser, Christoph Kayser

The power and phase of rhythmic brain activity prior to stimulus presentation can predict performance on psychophysical tasks (Henry & Obleser, 2012; Ng et al., 2012). We recently delineated two mechanisms by which power and phase shape sensory encoding and decision making in the auditory domain (Kayser et al., 2016). However, whether pre-stimulus oscillatory activity changes or remains stable across the lifespan remains relatively unexplored. In the current study, we investigated age-differences in the pre-

stimulus neuronal correlates of auditory perception and determined from which oscillatory networks these effects arise. We did so by combining a pitch judgement task, high-density EEG, and multivariate classification techniques. On each trial, participants listened to tone pairs embedded in noise, and were asked to identify which tone was highest in pitch. To investigate the neural activity underlying the decision-making process, we extracted time-frequency representations of the pre-stimulus period using a wavelet approach. We then used single-trial linear discriminant analysis to generate the neural component that best discriminates between conditions post-stimulus, and used this as a metric of sensory evidence. We then used regression analyses to quantify the relationship between pre-stimulus activity (power and phase), sensory evidence, and behavioral measures. Our results provide preliminary insights into how and when pre-stimulus oscillatory activity influences auditory perception, and how such influences may change with age.

#322 Time window of integration depends on the reliability of sensory inputs

Hans Colonius, Adele Diederich

Many models of multisensory behavior acknowledge that humans and animals can integrate sensory evidence from various sources to make decisions in a statistically near-optimal manner by taking into account the reliabilities of sensory modalities. For example, maximum likelihood estimation models states that the optimal way of estimation, in the sense of producing the lowest-variance estimate, is to add the sensor estimates weighted by their normalized reciprocal variances (Ernst & Banks, 2002, Science). Similarly, under the assumption of a common source, Bayesian inference models predict the multisensory estimate arising from the combination of both senses by weighing each input in proportion to its reliability (Kording et al, 2007, PLoSOne). However, in modeling reaction time (RT) data, like the race model or simple coactivation models, reliability of the different input modalities has typically not been taken into account, with the exception of a recent diffusion model for two-choice reaction times (Drugowitsch et al, 2014, eLife 3:e03005). Here we suggest a simple way to incorporate the effect of sensory reliability into the time window of integration (TWIN) model (Colonius & Diederich, 2004, JCogNeurosci). We hypothesize that, depending on which sensory-modality stimulus is first registered (“wins the race" in the first stage), the size of the window is dynamically adapted to the level of reliability of that sensory modality.

Specifically, whenever the less reliable modality wins, the window would be increased to give the more reliable modality a bigger chance to trigger multisensory integration. The hypothesis is tested by fitting the model to saccadic RTs to a visual target accompanied by an auditory distractor under four different levels of an auditory masker background with varying stimulus onset asynchrony values. Under the hypothesis, the estimate for the window width should increase with the level of the auditory masker.

#323 Does CRPS impair visuo-motor coordination in peripersonal space?

C. Verfaille, D. Cordova, L. Filbrich, O. Barbier, X. Libouton, V. Fraselle, D. Mouraux, A. Berquin, V. Legrain

Complex Regional Pain Syndrome (CRPS) is an affection characterized by chronic pain, motor and vegetative symptoms, but also by cognitive symptoms affecting body perception and representation. In addition, neglect-like deficits were clinically described. However, CRPS patients' performances at standard neglect tests are inconsistent and so far, we cannot conclude that these cognitive changes extend to stimuli presented in the space outside the body (i.e. peripersonal). Therefore, we used a line bisection task in a virtual reality environment in order to test whether upper-limb patients, in comparison to a matched control group, present an impaired perception and exploration of the peripersonal space around the affected hand. We hypothesized that these impairments would also be mediated by the vision of the affected hand and the feeling of where this hand is located (proprioception). To test these hypotheses, CRPS participants were asked to move a robotic handle with their unaffected hand in order to bisect the middle of lines projected on different positions on a horizontal semi-reflective mirror screen. Throughout the different testing conditions, they were asked to perform the task either in the workspace corresponding to their affected or unaffected body side, to put their affected hand inside or outside the workspace and to perform the task either while seeing or not their hands. Results showed that CRPS patients had a general bisecting bias towards the left side of space that were significantly bigger than deviations in the control participants, who only showed a tendency to bisect lines to the left. Our results are in line with previous studies stating a visuospatial deficit in the upper-limb CRPS population. General leftward biases are known as pseudoneglect, even in healthy population. We hypothesize that such an initially common visuospatial deviation could be exaggerated in CRPS

patients due to a global attentional deficit.Funded by the Fund for Scientific Research of the French-speaking Community of Belgium (F.R.S.-FNRS).

#324 Impaired development of audiovisual integration in autism and the effects of modality switching

Michael J. Crosse, John J. Foxe, Sophie Molholm

Simultaneous presentation of information from different sensory modalities often leads to faster responses than presenting the same information separately. Response times for multisensory stimuli have been shown to exceed the statistical facilitation predicted by the so-called “race model” (Miller, 1982), indicating integrated processing of the individual sensory streams. This ability to integrate multisensory inputs is gradually fine-tuned across middle childhood and adolescence (Brandwein et al., 2011). However, the developmental course of audiovisual (AV) integration that is observed in typically developing (TD) children is not seen in those with an autism spectrum disorder (ASD; Brandwein et al, 2012). Using the same audiovisual speeded reaction time (AVSRT) task, and data from nearly 300 participants, we demonstrated that this development is in fact delayed until adolescence in ASD participants and recovers considerably in adulthood. However, ongoing work by the Foxe Lab has revealed that random presentation of AV stimuli gives rise to the apparent redundant target effect reported in such AVSRT studies because of a behavioral cost to switching modality during the unisensory trials. To somewhat offset this “switch cost”, we separated trials into those preceded by a different stimulus (switch trials) and those preceded by the same stimulus (repeat trials). While AV integration was still observed in the repeat trials of TD participants, it was no longer observed in ASD participants. However, this race model violation in TD participants is likely due to a residual switching cost or “mixing cost”, as participants still had to deploy attentional resources across both sensory inputs. The fact that this mixing cost differentially affects behavior in TD and ASD participants suggests that it may in part reflect an underlying multisensory processing deficit in autism. To further investigate these behavioral differences, we examined neural responses to the switch and repeat trials recorded using high-density EEG.

#325 The role of temporal prediction in multisensory emotion perception

Ashley E. Symons, Wael El-Deredy, Jason R. Taylor, Michael Schwartze, Sonja A. Kotz

Emotion perception involves the rapid integration of dynamic sensory information from multiple modalities. Previous research has shown that information provided by facial and body expressions can be used to predict upcoming vocal expressions, with emotional expressions generating stronger predictions than neutral expressions, resulting in a reduction in the amplitude and latency of auditory event-related potential (ERP) components. However, it is unclear whether these predictions are based on the formal (content) or temporal (timing) structure of the expressions. In this EEG study we investigate whether emotional expressions generate stronger temporal predictions than neutral expressions when attention is explicitly directed to the time domain. Twenty-one participants viewed audiovisual clips of actors depicting fearful and neutral expressions. For each clip, the vocal expression could occur early, on-time, or late relative to the natural sound onset. To orient attention to the time domain, participants completed a synchrony judgment task in which they indicated whether the vocal expression occurred early, on-time, or late. Response accuracy was greater for fear compared to neutral, but only when the vocal expression occurred earlier than expected. ERP results revealed reduced N1 amplitudes and earlier latencies for fearful compared to neutral expressions. Moreover, there was a significant emotion by timing interaction, reflecting larger amplitudes when the vocal expression occurred on-time compared to early or latein time for the fear condition only. Therefore, when attention is directed to the relative timing of ecologically valid multisensory stimuli, fearful expressions elicit larger N1 amplitudes when the vocal expression occurs at the predicted point in time. Taken together, these findings suggest that temporal prediction cannot fully account for the N1 suppression effect for emotional compared to neutral expressions observed in previous studies, but that timing does differentially influence multisensory integration as a function of emotion.

#326 Amplitude-modulated sounds reduce peripheral flicker-detection thresholds

L. Jacob Zweig, Marcia Grabowecky†, Satoru Suzuki

† presenting author

Auditory-visual interactions in the real world involve sustained dynamic stimuli. While many laboratory studies focused on single isolated auditory-visual events, some investigated dynamic crossmodal interactions using amplitude-modulated (AM) sounds and visual flicker. These studies revealed slow (<4Hz) crossmodal-binding mechanisms that mediate conscious tracking of crossmodal synchrony and synchrony-based crossmodal attention capture, and revealed crossmodal temporal mechanisms that influence perceived number and rate of visual flashes by strongly weighting the more reliable auditory temporal processing. Do auditory dynamics also directly influence the processing of visual dynamic signals? We demonstrated that AM sounds reduce flicker-detection thresholds under specific conditions: (1) when flicker is presented in the periphery (not in the fovea), (2) when the modulation rates are relatively high (12 Hz) well beyond the 4Hz temporal limit for conscious tracking of auditory-visual synchrony, and (3) when the auditory-visual signals are either in-phase or 180° phase-shifted but not when they are 90° phase-shifted. This pattern of spatiotemporal results combined with relevant knowledge from neuroanatomy and neurophysiology suggest that AM sounds boost responses of frequency-doubling visual neurons to subtle flicker in a phase specific manner, potentially through direct neural connections from auditory cortex that target peripherally-tuned neurons in visual cortex.

#327 Using rotational apparent motion aftereffects to characterize influences of audiovisual dynamics on motion perception

Max K. Smith, Emmanuel Guzman-Martinez, Satoru Suzuki, Marcia Grabowecky

Previous studies ahve shown that auditory signals can facilitate visual motion perception by providing congruent feature information (Meyer & Wuerger, Neuroreport, 2001) or by increasing the salience of motion signals (Lewis & Noppeny, J. Neuro, 2010). Here we investigated the effects of auditory dynamics on the activation of direction-tuned visual neurons by examining auditory effects on motion aftereffects. Observers adapted to four evenly spaced circles unambiguously rotating around a fixation point (22.5° advance in

rotation angle per frame) while they concurrently heard brief bursts of high-pass-filtered (1500 Hz cutoff) white noise that were either in phase or in counterphase with the onset of apparent motion frames, or they heard no sound during adaptation. After 10 seconds of adaptation, observers were presented with an ambiguously rotating test display consisting of the same four circles alternating with its 45° rotated version. Observers initially saw the ambiguous test display rotate in the opposite direction (from the direction of the adapting rotation) and were instructed to press a button when this motion aftereffect ended. A longer lasting motion aftereffect would imply stronger activation of direction-tuned visual neurons. No sounds were presented during observation of the motion aftereffect. Both sound conditions (presented in phase or in counterphase with the apparent motion) resulted in a shorter motion aftereffect relative to the no sound condition. Interestingly, in phase sounds reduced the duration of the motion aftereffect significantly more than the counterphase sounds, suggesting that auditory-visual synchrony weakens activation of direction-tuned visual neurons. Implications of these results and their possible dependence on rate of motion will be discussed.

#328 Visual-tactile integration in solving 3D puzzles

Norman Hendrich, Jianwei Zhang

While humans perform everyday grasping and manipulation tasks almost effortlessly, uncommon manipulation puzzles involving object rotations can be surprisingly challenging. In this paper, we present a user-study involving a 3D labyrinth solving task; namely, unscrewing and opening "cryptexes" of different geometric complexity. While the test subjects could move and interact with the object freely, the labyrinth pattern is on the inside, and only those parts already solved become visible. This breaks with the life-long learned experience of visual-tactile interaction, and building a mental image of the object from tactile feedback alone turned out to be impossible for most of our test subjects. Object motion was recorded using the Polhemus magnetic tracking system, and our traces clearly show that random motions were often tried instead of systematic exploration using backtracking to recover from dead ends in the labyrinth.Most test subjects would solve the 2D version of the same labyrinths on paper within seconds; but even with the 2D pattern visible, the 3D manipulation task remained a problem, highlighting the cognitive effort required for mental rotation of 3D objects. On the other

hand, when shown a real-time semi-transparent rendering of the object, or a point-cloud of previously tried positions, our test persons would solve the task easily, pointing to the potential of visualization and augmented reality to help with unusual manipulation tasks.

#329 Investigating changes in the neural mechanisms of sensorimotor integration in children with autism following a 20-week intervention: a pilot feasibility study

Stefanie C. Bodison, Megan M. Herting, Elizabeth Sowell

Research has well documented that 80-94% of children with Autism Spectrum Disorder (ASD) have some kind of sensory abnormality and/or suffer from motor delays including postural instability and developmental dyspraxia. In children with ASD, it is theorized that one possible mechanism of developmental dyspraxia is altered sensorimotor integration, whereby the child is unable to successfully transform sensory representations into a motor response. In a recent pilot study, we developed a novel fMRI paradigm to compare the neural mechanisms of sensorimotor integration in children with ASD versus typically developing children. This fMRI paradigm proved successful in identifying differences in the neural architecture of sensorimotor integration in these children, thus setting the stage for expanded research on the influence of interventions on the altered brain mechanisms. In this study, we investigated the feasibility of using this fMRI paradigm to detect changes in the neural mechanisms of sensorimotor integration following a 20-week occupational therapy intervention. Five children with ASD between 6-8 years of age received baseline evaluations of sensory and motor function, and a battery of MRI assessments, including the use a novel fMRI paradigm of sensorimotor integration. Each child then received 40 sessions of occupational therapy intervention over a 20-week period of time, guided by an intervention manual aimed at improving overall sensory processing. Upon completion of the 20-week intervention, each child was reassessed using the same evaluation protocol as at baseline. After correcting for multiple comparisons (p's=0.05), the results following the occupational therapy intervention showed positive changes in the areas responsible for sensorimotor integration including the visual cortices, right parietal lobe, bilateral pre-motor areas, and the right pre-frontal cortex. Our results suggest that it is feasible to use this novel fMRI task paradigm of sensorimotor integration to detect changes in brain function following intervention.

#330 Perceptual deficits in audiovisual temporal integration in schizophrenia

Yeseul Kim, Seung-Hwan Lee, Chai-Youn Kim

It has been suggested that individuals with schizophrenia (SZs) show impairment in temporal processing of multisensory information (de Gelder et al., 2002; Foucher et al., 2007). However, the source of the deficit has not been specified since multiple factors are intermingled in most of the previous studies. In the present study, we investigated whether SZs show perceptual impairment in temporal aspects of audiovisual integration compared to normal controls (NCs) by utilizing sound-induced flash illusion (SIFI). SIFI is a phenomenon in which single visual flash is perceived as double flashes when accompanied by double auditory beeps (Shams et al., 2000). By manipulating inter-stimulus interval (ISI) of those simple visual and auditory stimuli, we expected to scrutinize audiovisual temporal integration in SZs. Sixteen SZs and seventeen NCs participated in our study. A white disk subtending 2° was presented for 13ms at 5° below the fixation against black background on the monitor. The visual flash was accompanied by two beeps (10ms each) of which ISIs ranging from 80ms to 320ms. One beep was always presented simultaneously with the flash and the other preceded or followed the flash. Participants were asked to judge the number of perceived flashes. Results showed that proportion of perceived double flashes decreased with longer ISIs in both SZs and NCs. Notably, SZs' illusory perception of SIFI lasted with longer ISIs (over 200ms) unlike NCs reporting double flashes only in short ISIs. In addition, the degree of reduction in SIFI with longer ISIs was negatively correlated with PANSS Negative symptoms, showing that SZs with higher Negative symptoms scores tend to experience enduring SIFI even with greater temporal distances between the two beeps. These results suggest that SZs have differential patterns of audiovisul integration from those of NCs', which is presumably based on the perceptually lengthened temporal binding window. Supported by NRF-2016R1A2B4011267 and NRF-2015R1A2A2A01003564.

#331 Dorsal and ventral premotor contributions to auditory timing: A continuous theta-burst stimulation study

Jessica Ross, John Iversen, Ramesh Balasubramaniam

It has been suggested that networks involved with movement planning play a role in some forms of time perception, but the specific contributions of premotor cortical areas

to time perception are unknown. Dorsal premotor cortex (dPMC) is part of the dorsal auditory stream, proposed by Patel and Iversen (2014) to be essential for musical beat-based timing. It is possible that ventral premotor cortex (vPMC) is more involved in visual timing (Ruspantini et al., 2011; Pollok, Krause, Butz, & Schnitzler, 2009) and dPMC is more involved in auditory timing (Pollok et al., 2009). In a previous study, we found that transcranial magnetic stimulation induced cortical down-regulation, continuous theta burst stimulation (cTBS), of left posterior parietal cortex, which is part of the dorsal auditory stream, interferes with accurate beat-based time perception (Ross, Iversen, & Balasubramaniam, in prep). In the current study, we are using cTBS to down-regulate vPMC and dPMC to test for causal premotor contributions to interval duration perception and beat-based timing. Our preliminary results (N = 15) suggest that down-regulating left dPMC raises interval duration perception thresholds by 29.67% (t(14)=-2.433, p=.029) and that down-regulating left vPMC raises interval duration perception thresholds by 45.43% (t(14)=-2.618, p=.020). Our data also show that down-regulating left vPMC lowers inter-beat interval deviation detection thresholds in a musical beatbased time perception task by 21.47% (t(14)=2.709, p=.017). These results support that left dorsal and ventral premotor areas play an essential role in auditory interval perception and that ventral premotor cortex may play an inhibitory role in musical rhythm perception.

#332 Oscillatory tracking of visual speech by auditory cortex: an intracranial EEG study

Pierre Mégevand, Jose Herrero† , Manuel R. Mercier, David M. Groppe, Nima Mesgarani, Ashesh D. Mehta, Michael Beauchamp, Charles E. Schröder

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Natural speech is multisensory: when we see the speaker, visual speech cues influence our perception of what is being said. The neuronal basis of this robust effect remains unclear; neuronal oscillations-ongoing excitability fluctuations of neuronal populations in the brain -represent a potential mechanism. Using intracranial recordings in humans, we show that auditory cortex tracks the temporal dynamics of purely visual speech in the phase of 1-6 Hz (delta/ theta) oscillations and phase-related modulations in neuronal firing. This tracking correlates with perceptual performance during silent lip-reading. Auditory cortical responses to purely visual speech can reconstruct the speech envelope, and this reconstruction is more accurate for more salient visual cues. Our results strongly

support the notion that visual speech influences auditory cortical processing of speech by phase-resetting its ongoing oscillations. Phase reset amplifies the representation of the speech stream as a whole and organizes the information contained in neuronal firing patterns.

#333 Electrical neuroimaging bridges non-human primate models and clinical research

Camille Roux, Véronique Moret , Jean-François Knebel, Micah M. Murray, Eric M. Rouiller, Gérard Loqet†

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Renewed interest in electroencephalography (EEG) in clinical research due to recent developments in electrical neuroimaging provides new expectations in identifying neurological biomarkers of brain pathologies. To track and validate such biomarkers a combined clinical and experimental approach is most effective. In animal models experiments allow pre- and post-lesion monitoring as well as invasive brain recordings. This would have huge implications in clinical work if we were able to bridge the gap. To tackle this problem, we worked on a cognitively mature model, the non-human primate, and applied electrical neuroimaging exactly as it is performed in clinical investigations. To test the approach, we engaged one animal in a manual dexterity task and went through a long training to habituate it to a customized high-density EEG cap. Results show that brain electric fields can be noninvasively collected in a behaving animal and thereafter used to seek putative generators in the brain. In our experimental conditions large scale brain networks of the motor function have been identified. In the broader context of nervous system diseases, clinically relevant EEG abnormalities should be compared with temporal dynamics obtained before and after lesion in the animal model. The additional given possibility to further explore underlying cellular processes (microcircuits) would contribute to elucidate pathology mechanisms and later, to develop better targeted therapies.

#334 The sound of salsa: enhancing the evaluation of piquancy by means of a customised crossmodally congruent soundtrack

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A growing number of crossmodal correspondences have been demonstrated recently between sound and basic tastes/aromas, but the impact of sound on more complex flavours and oral- somatosensory sensations is a relatively new area of exploration. Aims Uncover correspondences between basic auditory attributes and spiciness/piquancy. Verify whether spicy-congruent soundtracks might enhance spiciness ratings by acting on participants' sensory expectations. An online study (Experiment One) was conducted to determine the acoustical/music parameters that best match spiciness. The results were then used to compose a spicy soundscape that would be incorporated into subsequent experiments. A between-participants study (Experiment Two) was conducted to explore the effect of different background sound conditions on participants' expected and actual ratings of a novel dish tested in an ecologically-valid setting. A follow-up study (Experiment 3) was conducted with a spicier food sample (salsa) and the same sound conditions as Experiment Two. Finally, a study using both mild and hot salsa (Experiment 4) examined an interaction effect between sound condition and stimuli spiciness level. The research demonstrated, for the first time, the existence of crossmodal correspondences between spiciness/piquancy and congruent sound attributes - high pitch, fast tempo, high levels of distortion and cultural cues. The results also provided evidence that such correspondences can be used to modify people's evaluation of the expected and actual spiciness of foods, likely via a mechanism of inducing sensory expectations. The influence of music begins before participants even taste the food. The soundtrack appears to generate sensory expectations which can modify perceptions. Expectations about the taste of foods can change participants' perceived ratings of that taste, as long as the difference between expectation and reality is small.

#335 Investigate echolocation with sighted people

Alessia Tonelli, Luca Brayda, Claudio Campus, Andrea Serino, Monica Gori

Vision is the most important sense on the domain of spatial perception. Congenital blind individuals, that cannot rely on vision, show impairments in performing complex spatial auditory tasks. Interestingly, few blind individuals,naturally developed an acoustic technique, called echolocation, that help them to compensate the audio spatial deficit. Here we investigated if this technique can be also adopted used by sighted individuals to perceive and interact with the environment. Firstly, we tested the ability of novices sighted participants to perform an depth-echolocation task. We performed the task in different environments, i.e. anechoic and reverberant room, to evaluate the contribution of the environment. Secondly, we tested sighted participants in a more natural conditions, where they had to walk along a corridor and judge how it ended, i.e. turn left, right or closed. Moreover, we identified some motion variables that can help to predict the echolocation performance in sighted individuals. Thirdly, we showed that echolocation, not only helps to understand the external space, but could also influence how we perceive some characteristics of the space, as for example the peripersonal space (PPS), i.e. the space surrounding the body. To investigate that we evaluated the PPS before and after a detection echolocation task. All this information demonstrated that humans are sensible to echoes. Similarly to blind individuals, also sighted people can therefore learn to use this powerful technique to perceive and interact with the environment.

#336 Shared or distinct: Is attentional resource allocation across sensory modalities task-dependent?

Basil Wahn, Peter König

Human information processing is limited by attentional resources. That is, via attentional mechanisms, humans select a limited amount of sensory input to process while other sensory input is neglected. In multisensory research, a matter of ongoing debate is whether there are distinct pools of attentional resources for each sensory modality or whether sensory modalities share attentional resources. Recent studies have suggested that attentional resource allocation is in part task-dependent. That is, the recruitment of attentional resources across the sensory modality depends on whether processing

involves object-based attention (e.g., the discrimination of stimulus attributes) or spatial attention (e.g., the localization of stimuli). Here, we review recent results in multisensory research, including our own, related to this view. For the visual and auditory sensory modalities, findings suggest that object-based attention tasks recruit distinct resources. In contrast, for the visual and tactile sensory modalities, partly shared resources are recruited. Further, time-critical object-based attention tasks recruit shared resources across the sensory modalities. When humans perform an object-based attention task in combination with a spatial attention task, partly shared resources are recruited across the sensory modalities as well. Conversely, spatial attention tasks consistently involve shared attentional resources for the sensory modalities. In summary, findings suggest that the attentional system flexibly allocates attentional resources depending on task demands. We propose that such flexibility reflects a large-scale optimization strategy that minimizes the brain's costly resource expenditures and simultaneously maximizes capability to process currently relevant information.
Note, this abstract is based on: "Wahn, B., & König, P. (in press) Is Attentional Resource Allocation Across Sensory Modalities Task-Dependent? Advances in Cognitive Psychology"
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#337 Full-body size perception in healthy adults depends on viewpoint

Sarah D'Amour, Laurence R. Harris

Perceptual body size distortions have traditionally been studied in clinical populations using subjective, qualitative measures that assess only one type of body representation - the conscious body image. However, it is imperative to accurately determine baseline measures of how well healthy populations are able to judge their body size to understand how the body is implicitly represented in the brain. Here, we use a novel psychophysical method for determining perceived body size that taps into their implicit body representation. Participants were tested with the body presented in different viewpoints to see if performance changed for familiar and unfamiliar views. We expected that greater distortions would occur for the unfamiliar views. The Body Shape Questionnaire (Cooper et al., 1986) was also administered in order to determine if body dissatisfaction affects perceived size accuracy. Using a two-alternative forced choice (2AFC) design,

participants were sequentially shown two life-size images of their full body seen from one of three viewpoints: front, side, or back. In one image, the aspect ratio (with the horizontal or vertical dimension fixed) was varied using an adaptive staircase, while the other was undistorted. Participants reported which image most closely matched their own body size. The staircase honed in on the distorted image that was equally likely to be judged as matching their perception as the accurate image. From this, their perceived size could be calculated. Participants were not accurate at judging their full body size and differences occurred depending on the viewpoint presented. These results provide psychophysically robust measurements of how accurately healthy participants perceive the size of their full body, revealing distortions of the implicit body representation independent of the conscious body image.

#338 Exploring the relationship between synaesthesia, susceptibility to hypnosis and mental imagery.

Hazel Anderson

Synaesthetes have an unusual form of crossmodal perception where a percept or concept (inducer) causes a conscious and automatic experience in another modality (concurrent) such as graphemes triggering colour experiences. Phenomenology very similar to developmental grapheme-colour synaesthesia can be created using hypnosis, however cognitive hypnotic suggestions are experienced by only a small subset of people, generally those highly susceptible to hypnosis. Some people can manipulate their perceptual experiences comparably to hypnotic hallucinations using mental imagery alone and susceptibility to hypnosis is positively related to mental imagery. Synaesthetes also report higher levels of mental imagery in modalities linked to their synaesthetic inducer or concurrent. A range of evidence therefore links aspects of hypnosis, mental imagery and synaesthesia, however the relationship between synaesthesia and susceptibility to hypnosis is unknown. In this investigation, participants (~600) were screened for susceptibility to hypnosis using a screening measure which contains a variety of suggestion types, including cognitive perceptual hallucinations (Bowers, 1998). A brief synaesthesia type questionnaire (Eagleman, Kagan, Nelson, Sagaram, & Sarma, 2007) and vividness of visual imagery (Marks & Marks, 1973) were also recorded. This study will explore the relationship between these measures. Are synaesthetes more

susceptible to hypnotic perceptual hallucinations? And what can this tell us about synaesthetic crossmodal perception?

#339 Functional imaging of audio-visual selective attention in the monkey brain: How do lapses in performance affect brain modulations and the correspondence to humans?

Ross S. Muers, Heather Slater, Emma Salo, Teemu Rinne, Christopher I. Petkov

The cross-species correspondences and differences in how attention modulates brain responses in humans and animal models are poorly understood. We trained two monkeys to perform an audio-visual selective attention task during fMRI, rewarding them to attend to stimuli that changed in spatial location in one sensory modality while ignoring congruent or incongruent spatial changes in the other. Monkey fMRI identified modality specific temporal and frontal regions strongly modulated by auditory or visual attention. Surprisingly, auditory attention-related modulations were much more restricted in monkeys than humans performing the same tasks during fMRI.Further analyses ruled out trivial explanations, suggesting that labile selective-attention performance was associated with inhomogeneous influences on wide cortical regions in the monkeys. Interestingly, the pattern of activation during task performance more closely matches that observed in humans during auditory-selective attention, suggesting that activations in auditory cortex are similarly modulated by attention-engaging tasks in both species but are susceptible to being lost or altered during lapses in selective attention. More detailed behavioural analyses showed a specific cross-sensory influence on the monkeys' performance, in the form of a visual bias during auditory task performance with certain types of incongruent bimodal trials. To identify the brain areas susceptible to such cross-sensory influences during lapses in selective attention, the behavioural bias was estimated and submitted as a covariate for fMRI analysis. The result showed greater modulation of visual cortical areas when selective attention to the auditory stimuli lapsed. The findings provide considerable insights into how audio-visual selective attention modulates the primate brain, identify sources for 'lost' attention effects in monkeys in the form of cross-sensory brain modulations, and carry implications for modelling the neurobiology of human cognition with nonhuman animals.

#340 Measuring the sensitivity of tactile temporal order judgment in sighted and blind participants using the PSI method

C. Vanderclausen, A. Alamia, L. Filbrich, A. De Volder, V. Legrain

The perception of somatosensory stimuli on the body implies the use of different reference frames. It was shown that they are not only mapped according to a somatotopic reference frame, but also remapped according to spatial external coordinates. This remapping is thought to provide a common framework to integrate information from different sensory modalities into a multisensory representation of the body and the surrounding space. This remapping would be mainly shaped by visual experience. Indeed, it has been demonstrated that crossing the hands over the body midline affects the ability to perceive the temporal order of two tactile stimuli in sighted but not in early blind participants. This experiment aimed to test this hypothesis with sighted and congenitally blind participants using a vibrotactile temporal order judgment (TOJ) task adapted with an adaptive PSI method instead of the method of constant stimuli. This method adapts the stimulus onset asynchrony (SOA) presented in each trial according to the participant's performance in all the previous trials, allowing to measure precisely the temporal sensitivity of each in a task adapted to the ability of each. Results showed that all participants performed better with the hands uncrossed than with the hands crossed, irrespective of the group. These results suggest that both groups cannot be differentiated on the basis of the posture when the task is adapted to individual performance. Nevertheless, analyses of the SOAs presented to each group showed that the mode of the presented SOAs is significantly lower in the uncrossed compared to the crossed condition in sighted controls, but not in blind individuals. Taken together, these results indicate that a crossing-hand effect could be present in both groups, although more variable in the blind, suggesting that the remapping of tactile stimuli in external coordinates should not only be driven by visual experience.

#341 Auditory-only versus audiovisual word learning in children with cochlear implants

Jena McDaniel, Stephen Camarata, Rene H. Gifford, Michael Douglas, Paul Yoder

Background: Despite decades of debate[1], the extant literature offers minimal empirical evidence for whether unisensory auditory-only (AO) or multisensory audiovisual (AV) input is most beneficial to children with cochlear implants (CIs) for language learning, including

word learning, which is a persistent deficit in children with CIs[2]. Purpose: This study compares the effectiveness and efficiency of a receptive word learning intervention in AV versus AO conditions for preschool children with CIs. Methods: A single case adapted alternating treatments design is used with four preschool children with CIs. Pre-intervention language, speech production, auditory perception and multisensory integration skills characterize the participants and inform future studies. The AV, AO, and control word sets are balanced for phoneme audibility, phoneme visibility, and lexical neighborhood density. The dependent variable is the percent accuracy for identifying words receptively in probes that only provide auditory information. The examiner teaches participants to associate nonsense words with unfamiliar objects using a procedure adapted from Leonard and colleagues[3]. Only the presence or absence of access to speechreading cues differentiates the AV and AO conditions. Data Analysis: Results are interpreted for effectiveness and efficiency via visual analysis, the primary analysis method for single case research[4]. Preliminary data for Participant 1 shows evidence of word learning for AV and AO words, relative to the control set, with similar efficiencies (Figure 1). Implications: The proposed study may provide insight on how multisensory characteristics of word learning interventions affect their effectiveness for children with CIs and lead to a larger- scale study of multisensory processing for children with CIs. Larger studies could evaluate moderated differences between AV and AO conditions as a function of pretreatment characteristics. Additional clinical and research implications will be discussed.

#342 Impact of years of blindness on neural circuits underlying spatial perception.

Maria Bianca Amadeo, Claudio Campus, Monica Gori

Space representation is one of the hardest problems the brain has to face. Vision is the sensory system which mostly relies on retinotopic representation of space. The role that visual information plays in the development of auditory spatial abilities is still a matter of debate. Several studies suggest that blind people can partially compensate their visual impairment with greater sensitivity of other senses (Lessard, 1998; Roder, 1999). We showed that early visual deprivation can also impact negatively on spatial bisection tasks (Gori et al., 2014). We have recently investigated the neural correlates associated with this deficit with ERPs. A strong occipital cortical response, selective for spatial position of sounds, was observed in blindfolded sighted subjects but not in early blind individuals.

No difference appeared in the temporal bisection task. Here, we investigated the role of visual experience on spatial bisection abilities by involving late blind individuals. We recorded ERPs and collected psychophysical responses during spatial and temporal bisection tasks. Results suggest an association between duration of blindness, behavioral data and ERP responses. Specifically, a shorter period of blindness was linked to a higher performance and a stronger occipital contralateral activation in the spatial, but not temporal, bisection task. To conclude, here we show that the amount of time spent without vision may impact on neural circuits underlying spatial but not temporal auditory bisection performance in late blind participants.

#345 Looming sounds modulate visual size perception depending on the audiovisual spatial consistency

Daiki Yamasaki, Kiyofumi Miyoshi, Hiroshi Ashida

Sounds with increasing intensity (looming sounds) are perceived as approaching. It is known that looming sounds have significant characteristics that other sounds do not have (i.e., receding sounds), and affect even multisensory processing. Previous research showed that static visual stimuli paired with looming sounds were perceived larger than their actual size. However, the impact of looming sounds on the size perception of moving objects is unclear. Moreover, little is known about the influence of sounds presented from behind the body on vision. The current study aimed to investigate how sounds with changing intensity presented from front and rear space impact the size perception of dynamic visual objects. We recruited audiovisual stimuli those size and intensity changed monotonically. To manipulate the spatial position of the sounds, the loudspeakers were settled in front and behind of the participants. Participants performed the size-matching task while being exposed to the sounds. Our results showed that looming sounds caused participants to overestimate the size of expanding visual stimuli, but not of shrinking visual stimuli. Moreover, this influence was caused only by front-presented looming sounds, but not by rear-presented sounds. Receding sounds had no effect on vision. These results indicate that looming sounds modulate the size perception of moving objects depending on the audiovisual spatial consistency. This selective integration of audiovisual looming information contributes to faster detection of and reaction to approaching threats. Furthermore, we provided an evidence of the front-rear spatial asymmetry of audiovisual interaction, suggesting that human brain differently

processes various information based on the spatial properties of audiovisual stimuli. These findings provide a new framework for understanding the spatial principle governing audiovisual interaction.

#346 Cortical consequences of adult-onset partial hearing loss on audiovisual temporal processing and synchrony perception

Ashley Schormans, Brian L. Allman

The multisensory cortex is known to be highly dependent upon sensory experience. For example, we recently demonstrated that the lateral extrastriate visual cortex (V2L)-an area which normally integrates audiovisual stimuli-shows an increased responsiveness to visual stimuli following partial hearing loss (i.e., crossmodal plasticity). In the present study, we investigated the effect of hearing impairment on audiovisual temporal processing and the perception of simultaneity. Acute extracellular electrophysiological recordings were performed in adult male rats (n=6) two weeks following bilateral noise exposure, as well as in age-matched controls (n=6). Using an electrode inserted perpendicular to the cortical surface, local field potentials and spiking activity were collected simultaneously across all cortical layers of V2L in response to audiovisual stimuli delivered at various stimulus onset asynchronies (SOA). In a follow-up experimental series, a separate group of rats were trained to perform an audiovisual temporal order judgement (TOJ) task, and their perception of audiovisual temporal synchrony was tested before- and two weeks after noise exposure at various SOAs (i.e., 0, ±40, ±100 and ±200ms). As predicted, we found that noise exposure impaired audiovisual temporal processing in V2L, characterized by an increase in the latency of audiovisual stimuli presented at 20 to 0ms SOA, similar to the profile observed in visual cortex. Surprisingly, however, partial hearing loss did not disrupt performance of the TOJ task, as the timing at which the rats perceived the auditory and visual stimuli to be presented simultaneously was consistent before- and after noise exposure. Given that we have shown previously that hearing impairment appears to shift the functional border of the audiovisual cortex toward a neighboring, once-predominantly auditory area, it will be important for future studies to investigate how both crossmodal and intramodal, plasticity ultimately allow for the stable perception of audiovisual temporal synchrony following adult-onset hearing impairment.

Poster Abstracts

#347 Infant sensitivity to audiovisual timing driven by articulator-speech sound relationship

Heather Bortfeld, Kathleen E. Shaw, Martijn Baart

During interactions, people experience both auditory and visual speech unfolding together in time. Adults perceive audiovisual speech as coherent rather than as distinct streams; it is less clear whether infants do, as the developmental emergence of sensitivity to audiovisual timing is not well delineated. This is due at least in part to differences in the complexity of stimuli used in research with children of different ages. Establishing the trajectory of the emergence of this sensitivity is important as a variety of disorders are being traced to early difficulties with audiovisual timing. Thus, the current study was designed to test whether infants demonstrate sensitivity to audiovisual timing when provided sufficient information to do so. Infants between 5 and 9 months of age were tested using a single-screen looking-time task. They were shown sequential videos of a woman producing one of two trisyllabic pseudowords. One pseudoword contained highly visible articulations (mufapi), while the other contained less visible articulations (kalisu). Videos were edited to produce synchronous and asynchronous versions. For the asynchronous version, the audio stream preceded the visual stream by 300ms, while the timing was untouched in the synchronous version. Videos were blocked by pseudoword and by timing, with block order counterbalanced across infants. A median-split of infants by age resulted in a 2 (age: younger, older) x 2 (pseudoword articulation: visible, less visible) x 2 (timing: synchronous, asynchronous) mixed design. We observed main effects for pseudoword and age. Overall, infants preferred to look at more visible than less visible articulations, and younger infants looked longer than older infants. Beyond these general effects, older infants looked longer to asynchronous than synchronous videos but only when articulation was highly visible. We argue that infants' emerging sensitivity to timing is driven by the causal relationship between articulators and speech sounds.

#349 Mirror, mirror on the wall, is that me at all?

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Face recognition is an apparently straightforward but, in fact, complex ability, encompassing the integration of visual, somatosensory, and vestibular inputs (Tsakiris, 2008). Understanding how face identity shapes the interplay between these face-related multisensory cues could clarify the mechanisms of self-other discrimination. To this aim, we exploited the so-called “face inversion effect" (FIE), a specific bias in the mental rotation of face images (of other people): with respect to inanimate objects, face images require longer time to be mentally rotated from the upside-down (Yin, 1969). Via the FIE, which suggests the activation of somatosensory and vestibular representations, we assessed whether multisensory inputs have a different impact on self- versus other-face mental processing. Methodologically, to avoid the potential interference of the sensory feedback associated with musculoskeletal movements, we introduced the tracking of gaze direction to record participants' response. Response times from twenty healthy participants showed a larger FIE for self- than other-faces, suggesting that self-recognition is based on distinct multisensory integration mechanisms: the impact of somato-vestibular input on mental representation of faces varies according to identity. The present study puts lays the foundations of a quantifiable method to implicitly assess self-other discrimination. The implementation of this method in clinical and experimental environments can produce relevant translational benefits for the diagnosis of clinical conditions affecting face processing (e.g. prosopoagnosia), as well as for neurophysiological studies on self-other discrimination in animal research.

#350 When vision lies: Non-visual and visual navigation under different reliability levels

Shachar Maidenbaum, Michal Rabinovits, Amir Amedi

While human navigation does not depend on vision, it is considered to be the dominant sensory channel that humans use for navigation. However, what happens when this channel clashes with others, such as auditory navigation? We explored this by comparing navigation in several virtual environments, which enabled us to control subjects' sensory input and to manipulate the reliability of the visual input. These environments were each repeated under several different conditions: navigating using only audition (with the EyeCane Sensory Substitution Device), using only vision and in a series of “clash” trials in which the auditory channel was fully reliable but the visual channel was not. Specifically, either all walls were invisible, or 10% or 100% of the walls were visually wrong (invisible or fake walls masking openings). The auditory information was always reliable and subjects could solve all levels equally by ignoring vision and using only audition. Subjects were not instructed that the visual information may be unreliable and did not know which condition each trial was in.We found that all subjects self-learned to disregard unreliable visual information and rely on audition when needed, reflected also by increased suspicion of the visual information (e.g. scanning walls for masked openings). All subjects could complete all levels under all conditions. However, despite the potential ability to solve all levels equally by disregarding the visual input and using only audition, subjects reported significantly different levels of difficulty for the conditions, and a strong subjective preference for having the visual information even when aware that some of it, and even all of it, was false. This demonstrates both the ability to dynamically learn a new skill via an augmented sensory channel and to disregard the main modality typically used for it, but also the ingrained importance of the visual channel for human navigation.