

TORONTO2018

Academic Program

Welcome to IMRF 2018



We would like to personally welcome each of you to Toronto, Canada for the 19th Annual International Multisensory Research Forum! Multisensory research continues to be an exciting and dynamic field. We hope you will enjoy this program of exciting scientific lectures and symposia, poster presentations, and networking forums that will benefit your research and, we hope, generate new collaborations!

Sincerely, IMRF 2018 Organizing Committee

General Information

Registration

The Registration Desk is located in the Chestnut Foyer (see "Maps" section) and will be open at the following times:

- Thursday, June 15th from 4:30 PM 7:00 PM
- Friday, June 16th from 8:30 AM 5:00 PM
- Saturday, June 17th from 8:30 AM 5:00 PM



Venue

The Chestnut Residence and Conference Center is the main venue for IMRF 2018 (see Map on next page). Located adjacent to the Yonge and Dundas Square and directly north of the city's Financial District and City Hall. Chestnut is in the heart of the downtown core. We are only a 5-min walk from St. Patrick subway station, a 10-min walk from the Toronto Eaton Centre, and a 10min from Toronto's Financial walk District.



Committees

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Fiona Newell	(Trinity College Dublin, Ireland)
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Jennifer Campos	(Toronto Rehabilitation Institute, Canada)
Ryan Stevenson	(Western University, Canada)
Vanessa Harrar	(Université de Montréal, Canada)

Conference Organizing Committee:

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Laurence Harris	(York University, Canada)
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Gerome Manson	(University of Toronto, Canada)
Damian Manzone	(University of Toronto, Canada)
Meaghan McManus	(York University, Canada)
Stefania Moro	(York University, Canada)

Maps

Chestnut Residence and Conference Center 89 Chestnut St., Toronto, ON M5G 1R3



Closest TTC Subway Station: St Patrick (Line 1) Closest Dundas Streetcar Stop: Dundas St West @ Chestnut Street Parking: Paid parking available on Chestnut St. south of the building



Conference Rooms will be on FLOOR 2

Toronto Reference Library (Banquet Dinner) 789 Yonge St, Toronto, ON M4W 2G8



Directions to the Toronto Reference Library:

- Walk north on Chestnut to Dundas Street
- Walk east to Dundas St West and Yonge
- Take subway line 1 Northbound towards Finch Station

Exit at Bloor-Yonge Station

Walk north on Yonge to the Reference Library

Interactive Map:

Recommendations (restaurants, bars, entertainment, etc.) are available on an interactive map on our website. See: imrf.info/wp_imrf/annual-meeting/toronto

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Date	Time	Program	Location
Thursday June 14 th	7:45pm – 8:45pm	Opening Keynote	Ballroom
Friday June 15 th	9:00am – 10:30am	Symposium 1: Recovering from Blindness	Ballroom
	10:45am -12:00pm	Talk Session 1: Audio-Visual Integration	Ballroom
	1:30pm – 2:15pm	Symposium 2: Progresses in Vestibular Cognition	Ballroom
	2:15pm - 3:15pm	Symposium 3: The relationship of crossmodal correspondences to language	Ballroom
	3:15pm – 4:45pm	Poster Session 1	Ballroom
	4:45pm – 6:00pm	Symposium 4: The Role of Experience in the Development of Multimodal Integration	Ballroom
Saturday June 16 th	9:00am – 10:30am	Symposium 5: Multisensory Integration and the Body	Ballroom
	10:45am -12:00pm	Symposium 6: Multisensory Integration and Aging	Ballroom
	1:30pm – 3:15pm	Talk Session 2: Audio-visual substitutions and illusions	Giovanni Room
	1:30pm – 3:15pm	Talk Session 3: Developmental Perspectives	Ballroom
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	4:45pm – 6:00pm	Talk Session 4: Music	Giovanni Room
	4:45pm – 6:00pm	Talk Session 5: Haptics and Body Schema	Ballroom
Sunday June 17th	9:00am – 10:15am	Symposium 7: Where is my hand? On the flexibility of multisensory calibration to encode hand positions and movements	Ballroom

Academic program at a glance

10:30am– 11:45am	Symposium 8: The Multisensory Space – Perception, Neural Representation and Navigation	Ballroom
1:00pm – 2:00pm	Closing Keynote	Ballroom

Opening Keynote – Multisensory Flavour Perception: Insights for/from the Spatial Senses

June 14th, 7:45pm – 8:45pm

Prof. Charles Spence Head of the Crossmodal Research Laboratory, Oxford University

Food is both fundamental to our survival and fun to study. Furthermore, there is nothing that gets your brain going quite like the sight/smell of one's favourite food when hungry.[1] And, as the eminent British biologist J. Z. Young once noted, it is perhaps no coincidence that the mouth and the brain lie so close together in most species.[2] No wonder then that the brain rapidly estimates the energydensity of potential food sources in the environment and devotes our limited attentional resources accordingly.[3] At the same time, however, it is much harder, practically-speaking, to study flavour (i.e., the chemical senses) than it is to study the spatial senses of vision, hearing, and touch. This means that insights/theoretical frameworks into multisensory flavour perception may come more easily from studying the spatial senses (think sensory dominance and Bayesian causal inference, or the notion of super- and sub-additive interactions) than from studying flavour perception directly.

One might also question whether any unique insights about multisensory perception have emerged from the study of the chemical senses. In this talk, I will suggest that the phenomenon of 'oral referral' has no equivalent in the spatial senses,[4] and that gustatory-olfactory integration does exhibit some special properties (such as when smells become 'sweet').[5] There are also challenging philosophical questions here around the very definition of flavour itself, and which senses are constitutive versus 'merely' modulatory of this most multisensory of our everyday experiences.[6] Ultimately, I want to argue that our understanding of multisensory perception, both in the case of the integration of the chemical senses, and when it comes to the spatial senses, will likely benefit through the incorporation of the study of flavour perception into the broader scope of multisensory research.

[1] Wang, G.-J., Volkow, N. D., Telang, F., Jayne, M., Ma, J., Rao, M., Zhu, W., Wong, C. T., Pappas, N. R., Geliebter, A., et al. (2004). Exposure to appetitive food stimuli markedly activates the human brain. NeuroImage, 212, 1790-1797.

[2] Young, J. Z. (1968). Influence of the mouth on the evolution of the brain. In P. Person (Ed.), Biology of the mouth: A symposium presented at the Washington meeting of the American Association for the Advancement of Science, 29-30 December 1966 (pp. 21-35). Washington, DC: American Association for the Advancement of Science. [3] Sawada, R., Sato, W., Toichi, M., & Fushiki, T. (2017). Fat content modulates rapid detection of food: A visual search study using fast food and Japanese diet. Frontiers in Psychology, 8:1033.

[4] Spence, C. (2016). Oral referral: On the mislocalization of odours to the mouth. Food Quality & Preference, 50, 117-128.

[5] Auvray, M., & Spence, C. (2008). The multisensory perception of flavor. Consciousness and Cognition, 17, 1016-1031.

[6] Spence, C., Smith, B., & Auvray, M. (2015). Confusing tastes and flavours. In D. Stokes, M. Matthen, & S. Biggs (Eds.), Perception and its modalities (pp. 247-274). Oxford, UK: Oxford University Press.

About the speaker: Professor Charles Spence is the head of the Crossmodal Research Laboratory in the Psychology Department of Oxford University. He is interested in our brains process information from our different senses to form the extraordinarily rich multisensory experiences that fill our daily lives. His research focuses on how a better understanding of the human mind will lead to the better design of multisensory foods, products, interfaces, and environments in the future and has major implications for the design everything from household products to mobile phones, and from the food we eat to the places in which we work and live. Charles has advised multinational companies on aspects of multisensory design, packaging, and branding, and has conducted research on human-computer interaction issues on the European Space Shuttle. He is currently working on problems associated with the design of foods that maximally stimulate the senses. He has been awarded the 10th Experimental Psychology Society Prize, the British Psychology Society: Cognitive Section Award, the Paul Bertelson Award, and the Friedrich Wilhelm Bessel Research Award from the Alexander von Humboldt Foundation in Germany, not to mention the 2008 IG Nobel prize for nutrition, for his groundbreaking work on the 'sonic crisp'! He is the author of "Gastrophysics: the new science of eating", "The Perfect Meal: the Multisensory Science of Food and Dining" (with Betina Pigueras-Fiszman), "In touch with the Future: the sense of touch from cognitive neuroscience to virtual reality" (with Alberto Gallace) and "The Multisensory Driver: implications for ergonomic car interface design" (with Cristy Ho).

Closing Keynote – Crossmodal interactions in perception, memory and learning: on the scene and behind the scene

June 17th, 1:00pm – 2:00pm

Ladan Shams, Ph.D. UCLA Psychology Department

What are the principles that govern crossmodal interactions? Comparing human observers' multisensory perception with that of a Bayesian observer, we have found that humans' multisensory perception is consistent with Bayesian inference both in determining when to combine the crossmodal information and how to combine them. The former problem is a type of causal inference. Causal inference, which has been largely studied in the context of cognitive reasoning, is in fact a critical problem in perception. Our Bayesian causal inference model accounts for a wide range of phenomena including a wide range of multisensory illusions, as well as counter-intuitive phenomena such as partial integration and negative gain. In accounting for both perception of objects in the environment as well as perception of one's own body, our findings suggest that the same computational principles govern perception of the world and self.

Crossmodal interactions also play an important role in various types of learning and memory. We have found that multisensory experience enhances and accelerates unisensory perceptual learning, it instantaneously recalibrates unisensory representations, and improves unisensory episodic memory. These findings show that crossmodal interactions not only affect perception when signals from multiple modalities are present, but also influence the subsequent unisensory processing. In fact our recent findings show that in some cases, crossmodal interactions can aid learning even in the absence of multisensory experience: training in auditory modality produced substantial visual learning where training visual training failed to produce any significant learning. In other words, outsourcing the training to a different modality was key to learning. I will discuss the variety of ways in which crossmodal interactions can benefit learning and memory. Altogether, these findings suggest that crossmodal interactions influence both multisensory and unisensory perception, memory and learning in a robust and rapid fashion.

About the Speaker: Ladan Shams is a professor of Psychology, BioEngineering, and Neuroscience at UCLA, and the director of the Multisensory Perception Laboratory at UCLA. Dr. Shams received her Ph.D. in Computer Science at USC and her postdoctoral training in Cognitive Neuroscience at Caltech. Dr. Shams' research interests focus on multisensory perception and learning in humans. Dr. Shams has served as Associate Editor of Frontiers in Integrative Neuroscience, and Frontiers in Human Neuroscience, as an Action Editor of Psychonomic Bulletin & Review, and is on the editorial board of Multisensory Research. Dr. Shams is a member of the National Science Foundation College of Reviewers, the Society for Neuroscience, the Vision Sciences Society, and the International Multisensory Research Forum. She was featured by Chronicle of Higher Education as one of "five scholars to watch" and is frequently consulted as an expert by media outlets such as NPR, BBC and CNN.

Symposium 1 – Recovering from blindness: Learning to see using multisensory information

June 15th, 9:00am - 10:30am

Organizer: Marc Ernst & Irene Senna, Ulm University

Would a person born blind who regained sight via some surgical intervention be able to learn to 'see'? That is, would that individual be able to interpret the images that reach the retina and combine them with other senses in order to build a multisensory representation of the world, and to interact with the environment?

Surgically treating congenitally blind individuals (e.g., born with bilateral cataract) after extended periods of blindness provides a unique opportunity to study the development of visual skills, and the ability to combine vision with other senses.

For example, whether newly sighted individuals can learn to use their vision to recognize objects previously recognized only through touch, and to build multimodal representation of objects is still an open question. Behavioural and neural compensatory mechanisms in other sensory modalities are normally associated with blindness, but are such compensatory mechanisms maintained after sight restoration? Moreover, is the developmental path of such individuals similar to normal visual learning in early childhood and which are the factors that might limit perceptual learning? Deprivation from vision during the so-called critical periods might result in irreversible changes impairing the ability to interpret crucial aspects of visual and multisensory scenes. Are there critical periods for the development of the ability to integrate multisensory signals and to use vision for guiding action?

The proposed symposium aims to shed light on the development of visual and multisensory skills after sight restoration. In particular, the focus of the symposium will be on acquisition of visual function from multisensory information, and the use of these new perceptions for guiding actions.

S1.1 Learning to See Late in Childhood

Pawan Sinha Department of Brain and Cognitive Sciences, MIT

'Project Prakash' is an initiative launched over a decade ago with the goal of providing sight surgeries to blind children from medically underserved communities in the developing world. In pursuing this humanitarian mission, the project is helping address questions regarding brain plasticity and learning. Through a combination of behavioral and brain-imaging studies, the effort has provided a picture of the landscape of visual learning late in childhood and has illuminated some of the processes that might underlie aspects of such learning. I shall present an overview of some of our studies, which highlight the point that evidence of proficiencies as well as deficiencies in children's performance after sight onset is potentially informative about the nature of developmental processes. Both of these kinds of results have pointed to theoretically interesting questions that we have attempted to address using computational techniques.

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S1.2 How experience shapes brain specializations in the absence of vision Amir Amedi

Hebrew University of Jerusalem

I will discuss work aiming at unraveling the properties driving the sensory brain organization and at uncovering the extent to which specific unisensory experiences during critical periods are essential (or not essential) for the development of the natural sensory specializations. Our work focused on two fundamental discoveries: 1- Using the congenitally blind adult brain as a working model from a brain developing without any visual experience, we documented that essentially most if not all higher-order 'visual' cortices do maintain their anatomically consistent category-selectivity (e.g., for body shapes, letters, numbers or faces) even if the input is provided by an atypical sensory modality learned in adulthood, and that such task-specific sensory-independent specializations emerge after few hours of specific training (e.g. Abboud et al., 2015 Nat Comm; Amedi et al Trends Cog Sci 2017). Our work strongly encourages a paradigm shift in the conceptualization of our sensory brain by suggesting that visual experience during critical periods is not necessary to develop anatomically consistent specializations in higher-order 'visual' regions. We also propose the potential mechanisms underlying the emergence of sensory brain specializations independently of visual experience: a) pre-programmed sensory-independent task-specific computations that each specialized area/network processes (e.g., shape analysis for letter symbols independently of the sensory modality); and (b) partly innate network connectivity biases linking each specific cortical area to the rest of the brain (Heimler et al., 2015 Curr Opin Neurobiol; Hannagan et al., 2015 TICS; Amedi et al., 2017 TICS). Our emphasis on the task-selective and sensory independent brain organization also led to a paradigm shift in rehabilitation by suggesting that multisensory rather than unisensory training might be more effective in cases of sensory restoration (e.g. Reich et al Curr Opion in Neuorl; Heimler et al., 2015 Curr Opin Neurobiol; Amedi et al TICS 2017).

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S1.3 Motion processing after sight restoration: No competition between visual recovery and auditory compensation

Davide Bottari^{*}, R. Kekunnaya, M. Hense, N. F. Troje, S. Sourav, B. Röder IMT School for Advanced Studies Lucca

In the present study we tested whether functional adaptations following congenital blindness are maintained in humans after sight-restoration and whether they interfere with visual recovery. It has been shown that early permanently blind individuals outperform sighted controls in auditory motion processing and that auditory motion stimuli elicit activity in typical visual motion areas. Yet it is unknown what happens to these behavioral adaptations and cortical reorganizations when sight is restored. We employed a combined behavioral-electrophysiological approach in a group of sight-recovery individuals with a history of a transient phase of congenital blindness lasting for several months to several years. They, as well as two control groups, one with visual impairments, were tested in a visual and an auditory motion discrimination experiment. Task difficulty was manipulated by varying the visual motion coherence and the signal to noise ratio, respectively. The congenital cataract-reversal individuals showed lower performance in the visual global motion task than both control groups. At the same time, they outperformed both control groups in auditory motion processing suggesting that at least some compensatory behavioral adaptation due to the congenital blindness was maintained. Alpha oscillatory activity during the visual task was significantly lower in congenital cataract reversal individuals and they did not show ERPs modulated by visual motion coherence as observed in both control groups. In contrast, beta oscillatory activity in the auditory task, which varied as a function of SNR in all groups, was overall enhanced in congenital cataract reversal individuals. These results suggest that intramodal plasticity elicited by a transient phase of blindness was maintained and might mediate the prevailing auditory processing advantages in congenital cataract reversal individuals. By contrast, auditory and visual motion processing do not seem to compete for the same neural resources.

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S1.4 A brief period of early visual deprivation alters cross-modal interactions

Batsheva Hadad University of Haifa

We examined whether a short and transient period of visual deprivation early in life is sufficient to induce lifelong changes in how the different sensory modalities interact and integrate. The first set of experiments examined visual dominance in a group of adults who had been treated for congenital bilateral cataracts during early infancy compared to a group of normally sighted controls. A version of the Colavita paradigm was used with a task requiring simple detection of visual and auditory targets, presented alone or in combination. The results showed that although the absence of early visual input is shown to increase sensitivity (reducing thresholds) for simple auditory inputs, it does not prevent the development of visual over auditory dominance. Another set of experiments examined the links between magnitude estimation across modalities in the two groups, measuring JNDs for a standard stimulus of 250 ms duration in one modality (e.g., Gaussian blobs in the visual domain), while embedded within stimuli of the other modality (e.g., pure tones). In each case, stimuli were presented within either a relatively narrow range of standard durations of 200 and 300 ms, or within a wider range of 100 and 400 ms. In the normally sighted controls, the range of magnitude affected discrimination thresholds, producing greater JNDs for wider ranges of stimulus magnitudes. Auditory context affected perceptual resolutions in vision, and visual context affected those in the auditory domain. In comparison to controls, cataract-reversal patients showed greater context effects of auditory stimuli on the perceptual resolutions in vision while reduced context effects of visual stimuli on the perceptual resolutions in audition. These results reveal that the absence of visual input early in life does not prevent the development of sensory dominance but modulates audiovisual interactions such that the effects of auditory input on vision are enhanced.

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S1.5 Impairment of automatic "vision for action" functions in the newly sighted, following prolonged visual deprivation

Ayelet McKyton*, Ehud Zohary Hebrew University of Jerusalem

The ultimate goal of vision is to direct action. Some of our actions are triggered by automatic processes elicited by observing others' actions: Infants can recognize the target of gaze of others, and direct their gaze to the same object within months from birth (termed "shared gaze"). Similarly, we are faster and better imitating actions when they are spatially congruent with others' actions. Still, it is unclear if these automatic actions, elicited by viewing others, are innate or require visual experience to develop. We tackled this issue by studying a unique group of newly-sighted children that suffered from dense bilateral cataract from early infancy. After cataract removal surgery, their visual acuity typically improved allowing most of them

to recognize hand actions or gaze direction. We then tested whether viewing a hand action (performed by others), would facilitate the responsecompatible action and slow the incompatible one (automatic imitation effect). We also checked whether a pre-cue (showing a face with a specific gaze direction) would facilitate reaction to the gaze-compatible target (when compared to the gaze-incompatible location). The newly-sighted were less affected by task-irrelevant viewed-actions (hand action or gaze direction) than controls even two years after the operation. This strongly suggests that visual experience is necessary for the development of automatic imitation and shared gaze behaviour. At the very least, our results indicate that if these behaviours were based on innate mechanisms, they are clearly susceptible to long periods of visual deprivation.

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S1.6 Multisensory perception for action in newly sighted individuals *Irene Senna, Sophia Pfister, Marc Ernst* Ulm University*

In our daily life we constantly and effortlessly integrate vision with other sensory signals to build knowledge of the world, and to generate and guide actions. However, would you be able to integrate multisensory signals and to plan visually guided actions if you were deprived of vision during early development? We tested Ethiopian children who were classified congenitally blind as they suffered from dense bilateral cataract during early post-natal development, and were surgically treaded years later (5-19 yo). In a series of perturbation experiments, we assessed these individuals' ability to integrate visual information with other sensory signals, and to use visual feedback to guide actions. For instance, we asked participants to haptically explore objects while simultaneously looking at them through a magnifying lens (thus, inducing a discrepancy between senses). With such perturbation tasks, we aimed to investigate whether newly sighted individuals are able to integrate multisensory signals and make use of this newly acquired sense. In other tasks, we asked participants to wear prism goggles that shifted the apparent location of the target (i.e., inducing a systematic error between the apparent target's position and the motor command needed to reach it). With this task we tested whether cataract reversal individuals are able to minimize the systematic errors by recalibrating the sensorimotor systems, as sighted individuals do. The results provide important insights into their sensorimotor learning skills, which are essential for using vision to guide actions. Preliminary results suggest that sight-recovered children weigh vision systematically less compared with typically developing-children, and are less able to recalibrate the sensorimotor system. This suggests that the newly sighted make use of

the visual sense in the concert with the other senses, but also that they may require time to fully exploit its potentials.

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Talk session 1 – Audio-Visual Integration

June 15th, 10:45am - 12:00pm

T1.1 A common mechanism processes auditory and visual motion David Alais University of Sydney

Neuroimaging studies suggest human visual area V5, an area specialised for motion processing, responds to movement presented in the visual, auditory or tactile domains. Here we report behavioural findings strongly implying common motion processing for auditory and visual motion. We presented brief translational motion stimuli drifting leftwards or rightwards in either the visual or auditory modality at various speeds. Using the method of single stimuli, observers made a speed discrimination on each trial, comparing the current speed against the average of all presented speeds. Data were compiled into psychometric functions and mean perceived speed was calculated. A sequential dependency analysis was used to analyse the adaptive relationship between consecutive trials. In a vision-only experiment, motion was perceived as faster after a slow preceding motion, and slower after a faster motion. This is a negative serial dependency, consistent with the classic 'repulsive' motion aftereffect (MAE). In an audition-only experiment, we found the same negative serial dependency, showing that auditory motion produces a repulsive MAE in a similar way to visual MAEs. A third experiment interleaved auditory and visual motion, presenting each modality in alternation to test whether sequential adaptation was modality specific. Whether analysing vision preceded by audition, or audition preceded by vision, negative (repulsive) serial dependencies were observed: a slow motion made a subsequent motion seem faster (and vice versa) despite the change of modality. This result shows that the motion adaptation was supramodal as it occurred despite the modality mismatch between adaptor and test. We conclude that a common mechanism processes motion regardless of whether the input is visual or auditory.

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T1.2 Effects of horizontal and vertical discrepancy of visual-auditory stimuli on reaction time: Multisensory integration or exogenous spatial attention? A TWIN analysis Hans Colonius Oldenburg University

A classic behavioral finding in multisensory research is that the speed of a response to a stimulus of one modality is modulated by the spatiotemporal co-occurrence of a stimulus from another modality, even when subjects are instructed to ignore the auditory non-target (focused attention paradigm). Here we report a manual RT experiment with visual targets and auditory non-targets aligned either horizontally or vertically. Average reaction time (RT) to a visual target, when an acoustic non-target was presented 250 ms or less prior to the target, was reduced depending on the spatiotemporal configuration of the stimuli. Specifically, facilitation was larger when stimuli were presented in azimuth compared to elevation, and it increased when the spatial distance between target and non-target decreased. However, this spatial effect diminished the closer in time both stimuli were presented. Findings like this have raised the issue of whether RT facilitation in this context should be attributed to genuine multisensory integration (MSI) or simply an exogenous spatial attention (ESA) effect (e.g., Van der Stoep et al, 2015 APP). Here we develop a new version of the time window of integration (TWIN) model presented in Diederich & Colonius (2008) ExpBrainRes). The model allows both MSI and ESA to occur in one and the same trial but, depending on the temporal alignment of target and nontarget, only integration, only attention, or neither of them may occur. Moreover, the model yields numerical estimates of the contribution of both MSI and ESA and their possible interaction. First quantitative and qualitative tests of the model with data from the above experiment suggest that it can account for the observed pattern of results.

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T1.3 Generalizing audio-visual integration: what kinds of stimuli have we been using?

Michael Schutz McMaster University

The tension between experimental control and ecological validity presents continual challenges in psychological research. In particular, prominent figures in audition have long voiced concern (Gaver, 1993; Neuhoff, 2004) with the simplistic sounds used in perceptual experiments, which pose barriers to understanding the processes involved in listening to natural sounds. My team's work on audio-visual integration illustrates this challenge, documenting findings at odds with widely accepted theory when assessing both the duration (Schutz & Lipscomb, 2007) and temporal order (Chuen & Schutz, 2016) of audio-visual stimuli. These surprising breaks stem from clear differences between the complex structure of natural sounds in contrast to simplistic beeps, raising important questions about the

degree to which theories derived from artificial tones generalize beyond the laboratory.

To contribute to our understanding of stimuli used in auditory perception research, my team recently completed a survey of 1000 experiments drawn from hundreds of studies across the complete history of four key journals: Journal of Experimental Psychology, Attention, Perception & Psychophysics, Journal of the Acoustical Society of America, Hearing Research. This provides the first comprehensive overview of auditory stimuli, tabulating temporal and spectral attributes, as well as duration, frequency, and loudness. Curiously, it appears researchers failed to define the temporal structure of 38% of stimuli from these prominent studiesNan important aspect of sound playing a crucial role in audio-visual integration (Grassi & Casco, 2012; Schutz & Kubovy, 2009). More importantly, over 85% of the stimuli encountered in this wide range of experiments fail to exhibit temporal variation beyond simple ramped onsets and offsets. My talk will review the key findings of this novel survey, with a particular focus in implications for interpreting recent findings from the audio-visual integration literature.

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T1.4 Concurrent Unimodal Learning Enhances Multisensory Responses of Symmetric Crossmodal Learning in Robotic Audio-Visual Tracking Danish Shaikh

University of Southern Denmark

Crossmodal sensory cue integration is a fundamental process in the brain by which stimulus cues from different sensory modalities are combined together to form an coherent and unified representation of observed events in the world. Crossmodal integration is a developmental process involving learning, with neuroplasticity as its underlying mechanism. We present a Hebbian-like temporal correlation learning-based adaptive neural circuit for crossmodal cue integration that does not require such a priori information. The circuit correlates stimulus cues within each modality as well as symmetrically across modalities to independently update modality-specific neural weights on a moment-by-moment basis, in response to dynamic changes in noisy sensory stimuli. The circuit is embodied as a nonholonomic robotic agent that must orient a towards a moving audio-visual target. The circuit continuously learns the best possible weights required for a weighted combination of auditory and visual spatial target directional cues. The result is directly mapped to robot wheel velocities to illicit a multisensory orientation response. Trials in simulation demonstrate that concurrent unimodal learning improves both the overall accuracy and precision of the multisensory responses of symmetric crossmodal learning.

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T1.5 Differential effects of the temporal and spatial distribution of audiovisual stimuli on cross-modal spatial recalibration Patrick Bruns

University of Hamburg

Auditory spatial representations are constantly recalibrated by visual input. Exposure to spatially discrepant audiovisual stimuli typically results in a localization bias (ventriloguism aftereffect, VAE), whereas exposure to spatially congruent audiovisual stimuli results in an improvement (multisensory enhancement, ME) in auditory localization. In previous studies of VAE and ME, audiovisual stimuli have typically been presented at a steady rate of one or two stimuli per second (i.e., 1-2 Hz) with a fixed spatial relationship between the auditory and visual stimulus. However, it is known from unisensory perceptual learning studies that presenting stimuli at a higher frequency of 10-20 Hz, which mimics long-term potentiation (LTP) protocols, often leads to improvements while low-frequency stimulation around 1-2 Hz leads to impairments in performance. Therefore, in Experiment 1 we tested whether cross-modal spatial learning is similarly affected by the stimulation frequency. Unisensory sound localization was tested before and after participants were exposed to either audiovisual stimuli with a constant spatial disparity of 13.5; (VAE) or congruent audiovisual stimulation (ME). Audiovisual stimuli were either presented at a low frequency of 2 Hz or at a high frequency of 10 Hz. Compared to lowfrequency stimulation, the VAE was reduced after high-frequency stimulation, whereas ME occurred with both stimulation protocols. In Experiment 2, we manipulated the spatial distribution of the audiovisual stimulation in the low-frequency condition. Audiovisual stimuli were presented with varying audiovisual disparities centered around 13.5; (VAE) or 0; (ME). Both VAE and ME were equally strong compared to the fixed spatial relationship of 13.5; (VAE) or 0; (ME) in Experiment 1. Taken together, our results suggest that (a) VAE and ME represent partly dissociable forms of learning, (b) stimulation frequency specifically modulates adaptation to spatially misaligned audiovisual stimuli, and (c) auditory representations adjust to the overall stimulus statistics rather than to a specific audiovisual spatial relationship.

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Symposium 2 – Progresses in Vestibular Cognition

June 15th, 1:30pm - 2:15pm

Organizer: Elisa Raffaella Ferré, Royal Holloway University of London

The vestibular system is essential for successful interactions with the environment, providing an absolute reference for orientation and gravity. Vestibular information has been traditionally considered a cue for basic behaviours, such as balance, oculo-motor adjustments, and self-motion. However, recent studies have highlighted the fundamental role played by the vestibular system in brain functions beyond reflexes and postural adjustment. These include vestibular contributions to several aspects of cognition, including multisensory perception, spatial representation, emotion, attention and body models. This symposium brings together international experts with their own unique interests to the vestibular system. Laurence Harris will present experimental results on vestibular-somatosensory interaction highlighting its role in perceiving the timing of sensory events. Elisa Ferré will focus on how vestibular inputs integrate with other sensory signals to generate coherent estimates of perceptual vertical. Finally, Christophe Lopez will illustrate the effect of vestibular stimulations on bodily self and self-other interactions. Speakers will discuss the fundamental and hitherto largely unsuspected role of vestibular signals in almost all aspects of cognition.

S2.1 Vestibular-Somatosensory Interactions Affect The Perceived Timing Of Tactile Stimuli

Laurence R. Harris* and Stefania S. Moro Centre for Vision Research, York University

Passive rotation has been shown to alter temporal order judgments (TOJs) for tactile stimuli delivered to the hands giving an advantage to the leading hand. Here we compare the effects of physical tilt to the left or right with the effect of pure sensory stimulation created by galvanic vestibular stimulation (GVS) (evoking illusory tilts towards the cathode side, either the left or right). During tilt to one side the effect of gravity on the otoliths is equivalent to a physical acceleration away from that side (e.g., tilt left is equivalent to accelerating rightwards). We therefore predicted a "leading hand advantage" for the hand opposite to the tilt direction. TOJ thresholds for both left-hand-first and right-hand-first touches were measured separately using interleaved adaptive staircases. The mean of these two thresholds is the point of subjective simultaneity (PSS). For both physical and illusory tilt the PSS was shifted towards the hand contralateral to the tilt – equivalent to

the "leading hand" during rotation. These results are discussed in terms of attention and direct sensory components evoking the "leading hand" bias. These findings add to the emerging understanding of the pervasive role of vestibular activity in many aspects of cognitive processing.

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S2.2 Vestibular and Somatic Signals for Verticality

Elisa R. Ferré* Royal Holloway University of London

On Earth, verticality defines what is "up" and what is "down" in the gravitational field. The vestibular receptors detect the direction of gravitational acceleration: when our head moves, the otoliths shift and signal to the brain head position relative to gravity. These vestibular signals are integrated with information from vision, proprioception, and viscera to form a cognitive representation of the vertical. Here we investigated how people perceive verticality for stimuli applied to the skin. A psychophysical subjective tactile vertical task has been combined with Galvanic Vestibular Stimulation (GVS). Brief left-anodal and right-cathodal GVS, right-anodal and left-cathodal GVS, or sham stimulation were delivered at random while participants judged the orientation of lines drawn on their forehead. GVS did not bias tactile verticality estimates. Conversely, roll-tilting participants' head induced a bias in verticality estimates toward the body neuraxis. This bias was present also for stimuli not aligned with the body midline. Distinct representations of verticality might coexist: a vestibular representation, based on the direction of gravity, adopted as reference for environmental verticality perception, and a somatic representation which is not based on any online vestibular-gravitational signal, nor on the midline. The neuraxis seems a critical reference for this latter representation.

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S2.3 Reciprocal interactions between own-body cognition and vestibular information processing

Christophe Lopez* CNRS and Aix Marseille University

I will summarize recent evidence showing the interplay between own-body cognition and vestibular information processing. First, I will present data showing that caloric vestibular stimulation applied to a group of 16 healthy participants interferes with the mental representation of their body structure and shape. The data highlight an overall predominance of the left vestibular

apparatus in modulating the perceived size of body parts, irrespective of the laterality of the body parts. Second, I will present results obtained in 350 otoneurological patients suffering from dizziness showing that vestibular disorders alter several aspects of self-and body perception and cognition, including the perceived shape and size of the body, body agency (the sense of being the agent of an action), body ownership and embodiment (the sense that the self is located within the physical boundaries of the body). Finally, the influence of cognition on vestibular information processing will be shown by a recent study linking social cognition to vestibular neurophysiology. We measured how observing passive motion of human influences vestibulo-spinal excitability. Healthy participants observed videos depicting passive rotations of their own body ('self' videos), someone else's body ('other' video) or an object of the same size ('object' video) in a headmounted display. At the same time, we measured vestibulo-spinal reflexes evoked by galvanic vestibular stimulation. The data show that vestibulospinal excitability decreased for 'self" and 'other' videos when compared to 'object' videos. The reduction was stronger for 'self' than 'other' videos. This indicates top-down (social) modulation of vestibular information processing and provides the first evidence that social cognition has a pre-reflective influence on vestibular processing.

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Symposium 3 – The relationship of crossmodal correspondences to language

June 15th, 2:15pm – 3:15pm

Organizers: Krish Sathian¹ & Charles Spence² ¹Penn State College of Medicine, Milton S. Hershey Medical Center ²Oxford University

Crossmodal correspondences are a very active field of study. A major issue is the nature of their relationship to language. In this symposium, we bring together a number of speakers to address this issue, based on recent work. Charles Spence, the symposium co-organizer, will lead off with introductory remarks. Next, Laura Speed will discuss the role of language in odor-color correspondences in synesthetes and non-synesthetes. This will be followed by a review of potential mechanisms underlying sound symbolism, by David Sidhu. Finally, Krish Sathian, the symposium organizer, will present findings on the neural basis of sound symbolic crossmodal correspondences.

S3.1 Introductory remarks

Charles Spence Oxford University

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S3.2 Language and odor-color correspondences

Laura Speed and Asifa Majid Radboud University and Max Planck Institute for Psycholinguistics

People can make consistent associations between odors and colors, and these associations have been shown to differ depending on how the odors are named. This suggests an interplay between odor-color correspondences and language. In this talk we will present data that suggests associations between odors and colors can support odor naming. We find that odor-color synaesthetes – individuals who have automatic and vivid color experiences when they smell odors – are better at naming odors than control participants who do not have synaesthesia. We also find that odor-color associations are more consistent for odors that are more nameable, for synaesthetes and controls. However, data from another experiment suggests that language does not directly affect odor-color correspondence online. In a second experiment, participants were asked to match colors to odors in three interference conditions: holding a verbal code in mind, holding a visual pattern in mind, or no interference. Although we again observed that more nameable odors had more consistent color associations, the verbal interference condition did not disrupt the odor-color matches. This suggests that odor-color associations do not arise via the explicit naming of odors. Overall, we propose that odor-color associations strengthen conceptual representations, which lead to stronger connections with language.

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S3.3 Mechanisms of sound symbolism

David M. Sidhu and Penny M. Pexman University of Calgary

Sound symbolism refers to an association between certain language sounds (i.e., phonemes) and particular perceptual and/or semantic elements (e.g., objects of a certain size or shape). The most well known example of this is the maluma/takete effect, in which phonemes like those in maluma are judged as good matches for round shapes, and phonemes like those in takete are judged as good matches for jagged shapes (Köhler, 1929). While the existence of these associations has been well documented, the mechanism underlying them is still not well understood. Here we review five proposed mechanisms for sound symbolism: 1) a statistical co-occurrence in the world between some phonetic feature and associated stimuli, that has been internalized; 2) a shared property among phonemes and associated stimuli, which may be perceptual or conceptual; 3) a common neural mechanism in the processing of phonemes and associated stimuli; 4) an evolved, species-general, association; and 5) patterns extracted from the lexicons of existing language. Importantly, these mechanisms need not be mutually exclusive and likely interact in the creation of sound symbolism. While sound symbolism is often considered an instance of crossmodal correspondence, we note that the involvement of complex linguistic stimuli in sound symbolism is an important distinction that creates additional complexities in the search for its underlying mechanism. Lastly, we report the results of a study that represents our first step in testing these proposed mechanisms. Adult participants rated a sample of nonwords and abstract shapes on 25 semantic differential scales; participants also rated the fit between nonwords and shapes. Results suggest that shared conceptual properties among nonwords and shapes contributes to shape sound symbolism. We consider these results in the context of the five proposed mechanisms.

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S3.4 Neural basis of sound-symbolic crossmodal correspondences

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

Departments of Neurology, Neural & Behavioral Sciences, and Psychology, Pennsylvania State University Departments of Neurology, Psychology and Winship Cancer Institute, Emory University

Crossmodal correspondences (CCs) occur between a variety of sensory stimuli (Spence, Attention, Perception & Psychophysics, 2011). Sound symbolism refers to the associations between the sounds of words and their meanings. This has often been studied empirically using CCs between auditory psedudowords and visual shapes; e.g., the pseudowords "takete" and "maluma" are associated with spiky and rounded shapes, respectively. Sound-symbolic associations have been suggested to underlie the origins of language and to form a continuum with synesthesia (Ramachandran & Hubbard, Journal of Consciousness Studies, 2001). Relevant to this idea, we reported earlier that synesthetes exhibit stronger sound-symbolic CCs than non-synesthetes (Lacey et al., European Journal of Neuroscience, 2016). Yet, little is known of how sound-symbolic CCs are processed neurally.

We examined the neural basis of sound-symbolic CCs using functional magnetic resonance imaging (fMRI). The auditory pseudowords "lohmoh" and "keekay" were used: these were previously shown to be rated as rounded or pointed, respectively. They were paired with visual shapes that had either rounded or pointed contours, presented simultaneously. When participants attended to the auditory stimuli to make a two-alternative forced-choice, sound symbolically incongruent visual shapes evoked stronger responses compared to congruent ones, in the anterior intraparietal sulcus and supramarginal gyrus bilaterally, and in the right postcentral sulcus, and left middle frontal and superior parietal gyri. Comparing these incongruency-related activations to functional localizers suggested relationships of the underlying neural processes to those involved in multisensory integration, magnitude estimation and phonology. In addition, these findings point to an important role for multisensory attention. Ongoing studies reveal significant correlations between the dissimilarity matrices for the perceptual ratings of pointedness and roundedness between a range of auditory pseudowords and visual shapes. We are currently investigating the relationship between corresponding neural dissimilarity matrices in neocortical regions that process these stimuli.

Supported by NEI

Symposium 4 – The Role of Experience in the Development of Multimodal Integration

June 15th, 4:45pm – 6:00pm

Organizer: Daphne Maurer, McMaster University

There are major postnatal changes in multimodal integration. This symposium will consider the role of experience in shaping those changes. First, David Lewkowicz will discuss normal human development during infancy. He will describe the transformation the rudimentary abilities present at birth over the first year of life by experience with specific languages and specific types of faces. Second, Daphne Maurer will discuss changes in the development of audiovisual integration in patients treated for dense congenital cataracts in one or both eyes, even when vision was restored during early infancy. Those results suggest that crossmodal re-organization begins to occur near birth but is compromised differentially by early deprivation to one versus both eyes. Third, Anu Sharma will consider a similar issue for patients deaf from an early age in one or both ears. Using high density EEG, she will illustrate responses of auditory cortex to visual and somatosensory stimuli after early deafness, with different patterns across patients that correlate with success with cochlear implants. Fourth, Steve Lomber will report on an animal model of such cortical re-organization after deafness: deafened cats show enhanced visual sensitivity and visual responsiveness in auditory cortex, but the extent of the changes depends on the age of deafening and the amount of acoustic experience preceding it. Finally, Takao Hensch will describe a mouse model showing the role of the factors controlling critical period plasticity in shaping the development of cortical audiovisual interactions. Collectively, the papers will present new insights by considering the role of experience in shaping the development of multimodal integration from multiple perspectives: development in humans and in animal models; the effects of normal input versus input altered by auditory or visual deprivation; and evidence from behavioural and cortical studies.

S4.1 Early Experience Shapes the Development of Selective Attention and Multisensory Processing in Human Infants David Lewkowicz Northeastern University

The everyday objects and events in an infant's world are often specified by multisensory attributes. For example, whenever infants interact with social partners, they can see and hear them talking. To perceive their social

partners as perceptually unitary and psychologically meaningful entities, infants must attend to their multisensory attributes and process them. We and others have found that multisensory processing is rudimentary at birth and that it improves gradually as infants grow and acquire experience. In this talk, I will review evidence from our lab indicating that early experience is critical for the emergence of multisensory processing in infancy. First, I will show that the multisensory world of young infants is relatively undifferentiated because of sensory limitations and lack of experience. Then I will show that infants gradually shed their primitive multisensory processing mechanisms in favor of increasingly more refined and mature ones and I will provide evidence that this developmental process is partly driven by experience-dependent narrowing of responsiveness to multisensory inputs. Narrowing will be illustrated by evidence from studies of infant matching of other-species faces and voices, matching of native and non-native auditory and visual speech, and discrimination of own and otherrace faces. Overall, these findings will show that infants initially exhibit paradoxically broad tuning and, thus, detect the multisensory unity of native and non-native multisensory inputs and that, as they acquire mostly nativeinput experience, they cease detecting the unity of non-native multisensory inputs. Finally, I will review findings from our recent studies of infant selective attention to fluent audiovisual speech and demonstrate that attention undergoes marked, experience-dependent, developmental changes during the first two years of life. I will conclude by highlighting the intricate relationship between selective attention and multisensory processing and the way that early experience affects the development of both processes.

Supported by Eunice Kennedy Shriver National Institute of Child Health and Human Development, Grant number: R01HD057116

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S4.2 The Development of Audiovisual Integration: New Insights from Adults treated for Congenital Cataract

Daphne Maurer, Yi-Chuan Chen, David Shore, & Terri L. Lewis McMaster University and The Hospital for Sick Childen

Patients treated for congenital cataract provide a natural experiment for investigating the role of visual input in perceptual development. Here, we considered the effects of early visual deprivation on the development of audiovisual integration in adults treated for unilateral or bilateral congenital cataract at 0.3-28.8 months of age (n=13/grp).

Simultaneity judgments. Controls showed a typical gaussian curve peaking when the flash slightly preceded the sound, a shift usually attributed to plastic adjustment for slower travel of sound than light. The curve for bilateral patients was abnormally wide, but only on the flash-leading side, the condition most plastic in normal adults (Chen et al., 2017). The curve for unilateral patients had a normal peak but was abnormally wide for both sound- and flash-leading sides as is found in typically developing children (Chen et al., 2016).

Fission illusion. Bilateral patients had a smaller illusion than controls, with less influence of the beeps on the perceived number of flashes. This pattern occurred despite evidence of auditory dominance in other tasks: they are faster than controls at detecting a beep and at switching attention from vision to audition (de Heering et al., 2016) and in fMRI images, show auditory activation of visual cortex (Collignon et al., 2015). Unilateral patients behaved like the control group, with a similarly robust illusion, which was normally modulated between centre (smaller) and periphery (larger).

Bilateral patients' abnormalities suggest that early visual input is necessary both to set up the neural substrate for later visual development and also to allow normal audiovisual integration. When input is missing to both eyes, even for just the first few months of life, auditory input establishes effective connections in "visual" cortical areas and leads to enhanced auditory processing, but at a cost to effective audiovisual integration. When the deprivation is unilateral, early input through just one eye may be sufficient to reduce that re-organization.

Supported by CIHR, NSERC, James S. McDonnell Foundation

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S4.3 Cross-Modal Plasticity in Deafness: Evidence from Children and Adults Fitted with Cochlear Implants

Anu Sharma University of Colorado, Boulder

Congenital deafness prevents the normal growth and connectivity needed to form a normally functioning sensory system– resulting in deficits in oral language and cognition in deaf children. Cochlear implants (CI) bypass peripheral cochlear damage, by directly stimulating the auditory nerve, making it possible to avoid many of the harmful effects of auditory deprivation. Patients who receive CI's provide a platform to examine the characteristics of neuroplasticity in the central auditory system. An important aspect of compensatory plasticity that is evident in deafness is the re-organization and re-purposing of auditory cortex by other sensory modalities known as cross-modal plasticity. We examined cross-modal plasticity from the visual and somatosensory systems in deaf children with bilateral deafness fitted with CIs and in deaf adults and children with single-

sided deafness fitted with CIs and related them to communication and cognitive outcomes. High-density 128 channel electroencephalographic (EEG) recordings to auditory, visual and somatosensory stimulation, tests of auditory-visual speech perception in noise and cognition were administered. Patients with cochlear implants showed activation of auditory cortical areas in response to visual and vibrotacticle stimulation, suggestive of crossmodal recruitment by the visual and somatosensory modalities. Cochlear implanted patients who had greater difficulty understanding speech in noise via their cochlear implant showed greater evidence of cross-modal recruitment. In persons with single-sided deafness the (unstimulated) cortex contralateral to the deaf ear showed greater evidence of cross-modal recruitment. Cochlear implantation appeared to reverse cross-modal reorganization in many (but not all) patients with single-sided deafness. Overall, our results show that compensation for degraded auditory input results in greater dependence on other modalities which serves to aid communication in real-world situations. Our results suggest that the alterations in neural circuitry that underlie compensatory cross-modal plasticity may be an important source of variability in outcomes for patients with CIs.

Supported by the US National Institutes of Health.

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S4.4 Short Periods of Perinatal Sensory Experience Change the Structure and Function of Auditory Cortex

Stephen G. Lomber and M. Alex Meredith University of Western Ontario (Canada) and Virginia Commonwealth University (USA)

Compared to hearing subjects, psychophysical studies have revealed specific superior visual abilities in the early-deaf, as well as enhanced auditory functions in the early-blind. The neural substrate for these superior sensory abilities has been identified to reside in the deprived cerebral cortices that have been reorganized by the remaining sensory modalities through crossmodal plasticity. Furthermore, the cartography of auditory cortex is altered following the loss of auditory input early in life. The current investigation examines how perinatal exposure to brief periods of acoustic stimulation alters the developmental trajectory of auditory cortex. Compared to hearing animals, movement detection, localization of a flashed stimulus in the visual periphery, and face discrimination learning are superior in congenitally deaf cats. These enhanced functions are localized to specific regions of deaf auditory cortex. To examine the role of acoustic experience in mediating these enhanced visual functions in the deaf, hearing animals were chemically deafened with ototoxic drugs at increasing ages postnatal. The animals had one to twelve weeks of acoustic exposure prior to deafness onset. In adulthood, the cats were trained and tested on the same visual tasks examined in the congenitally deaf cats. Overall, following twelve weeks of acoustic experience, no enhanced visual abilities could be identified. With only four weeks of acoustic exposure, the enhanced motion detection ability was not evident. These reduced levels of enhanced visual functions are correlated with changes in cortical cartography. As acoustic experience increased during development, the overall size of auditory cortex, and the size of individual auditory areas also expanded.

These results demonstrate that increasingly longer periods of perinatal acoustic exposure result in reduced enhanced visual abilities and an increased size of auditory cortex.

Supported by the Canadian Institutes of Health Research.

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S4.5 Enhanced cross-modal auditory response in primary visual cortex with altered critical period timing

Takao Hensch Harvard University, Boston Children's Hospital

Synesthesia is a condition wherein one sense is evoked by another. How this arises during development remains largely unknown. We investigated auditory responses and audiovisual interactions in the primary visual cortex (V1) of several mouse models to estimate the level of mixture across senses. Sound modulation of V1 spiking activity was temporally dynamic dependent upon the level of GABA-mediated inhibition. Acute optogenetic suppression of either parvalbumin- (PV) or somatostatin- (SOM) expressing inhibitory interneuron subtypes suggested their early or late recruitment by sound, respectively. Maturation of GABAergic circuits in V1 further dictates the timing of a critical period (CP), a developmental window of enhanced plasticity for visual receptive field properties. One role of maturing GABA circuit function during the CP was to dampen the net non-visual sensory influence. Orientation selectivity was thus impervious to sound specifically during the CP due to balanced amounts of sound-driven spike enhancement and suppression. Cross-modal activation of V1 persisted in dark-reared mice whose CP fails to close. Recent studies interestingly suggest a higher incidence of synesthesia among people with autism, which typically display a comorbid imbalance of excitatory/inhibitory (E/I) circuit function. Analysis of V1 auditory responses in the inbred BTBR mouse strain with autistic features revealed a robust contralateral bias to sound

stimuli. Early spike modulation of V1 by sound was shifted toward enhancement similarly across three different autism models (BTBR, SCN1A R1407X, Neuroligin3 R451C). Taken together, our results suggest that developmental E/I imbalance may be a common CP circuit dysfunction underlying autism and synesthesia.

Symposium 5 – Multisensory Integration and the Body

June 16th, 9:00am - 10:30am

Organizer: Jared Medina, University of Delaware

Body perception is inherently multisensory, with information from various senses combining to create a coherent sense of the body. Along with the well-explored problem of multisensory integration across different modalities, other factors also influence multisensory integration of the body. For example, information from different spatial representations with their own frames of reference need to be weighted and integrated. Furthermore, top-down information from stored representations of the body may be combined with bottom-up sensory input from different modalities, leading to perception. In this symposium, we will review recent evidence addressing how information from different spatial representations and modalities are integrated. Our first set of speakers will describe recent results highlighting how spatial representations of the body influence the processing of tactile cues and motor control. Our second set of speakers will describe recent results highlighting how representations of the body and of space generally can be manipulated through vision, galvanic vestibular stimulation, and tool use. Collectively, our session will leverage novel technologies, brain stimulation, computational modeling, and behavior to provide an updated perspective on the interplay between body representations and multimodal cue processing.

S5.1 Feeling a touch to the hand on the foot

Stephanie Badde^{1,2*}, Brigitte Röder², & Tobias Heed^{2,3}

- ¹ Department of Psychology, New York University
- ² Biological Psychology and Neuropsychology, University of Hamburg
- ³ Biopsychology and Cognitive Neuroscience, Bielefeld University

Where we perceive a touch presumably depends on somatotopic maps that code its location on the skin surface, as well as on parietal maps laid out to represent tactile locations in external space. However, the location of a touch is characterized also by non-spatial features such as the type of the stimulated limb. We found that healthy adults sometimes attribute brief tactile stimuli to completely wrong limbs. These errors were used to investigate the contributions of somatotopic, external and feature-based coding to touch localization. In each trial, two randomly selected limbs were successively stimulated, and participants indicated the perceived location of the first touch, choosing from all four limbs. Hands and feet were positioned uncrossed or crossed to disentangle the influence of somatotopically and

externally coded stimulus location. Although mostly being accurate, participants regularly reported touch at non-stimulated limbs. These phantom errors occurred preferentially at limbs of the homologous limb or on the same body side as the physical touch, with the former being much more frequent when the stimulated limb was crossed. Moreover, phantom errors did not depend on external-spatial alignment of stimulus and erroneously responding limb, but on alignment of the responding limb with the stimulus's body side. The phenomenon of phantom errors indicates that touch can be perceived at a limb without any peripheral tactile input to the respective somatosensory map region or adjacent areas. Moreover, the pattern of phantom errors suggests that although body posture influences tactile localization, touch is attributed to a limb based on anatomically defined features that abstract from spatial coding.

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S5.2 Canonical computations mediate cue combination in touch

Jeffrey M. Yau* & Md. Shoaibur Rahman Department of Neuroscience, Baylor College of Medicine

Our remarkable ability to sense and manipulate objects bimanually likely requires the integration of sensory inputs that signal both the local events occurring at the fingertips (touch) and the relative locations of the hands (proprioception). Yet, the neural computations that support bimanual touch are unknown. Here, we show that tactile signals experienced on one hand systematically influence the perceived frequency of vibration cues experienced on the other hand. Moreover, the strength of bimanual interactions in the frequency domain, indexed by bias and threshold changes, vary according to the proximity of the hands: Hands held further apart interact less than hands held closely together. Surprisingly, a different pattern of bimanual interactions is observed when subjects perform an analogous intensity discrimination task: Distractors only attenuate the perceived intensity of a vibration cue and the magnitude of attenuation is independent of hand location. These idiosyncratic cue combination patterns could be well explained by distinct computational models. Our collective results reveal feature-specific cue combination patterns in bimanual touch that are consistent with canonical computations like normalization.

S5.3 Moving with a growing body: development of visual-proprioceptive integration for hand motor control

Marie Martel* & Tobias Heed

Faculty of Psychology and Sports Science and Center of Excellence in Cognitive Interaction Technology, Bielefeld University

Spatial integration across sensory modalities supports fine-tuned motor control. During movement, both vision and proprioception signal the location of our body parts. Yet, we lack knowledge on how interactions between multisensory integration and motor control develop in humans. In children, some multisensory functions develop over a protracted period, and adult-like weighted integration that yields to optimality principles is not evident until at least 8-10 years of age. At present, it is unclear whether a similar protracted development occurs for the use of multisensory information in motor control.

Here, we investigated the performance of 4-10-year-old children in unimanual and bimanual motor tasks with proprioceptive, visual, and proprioceptive-visual input. Children operated an apparatus that had two handles that could move in circles. Handle positions could be displayed as cursors on a cover over the workspace. Children had to symmetrically coordinate circular movements with the two unseen hands (proprioceptive only), or additionally received cursor feedback (proprioceptive-visual). In a third condition, they coordinated one hand with the circular movement of a cursor (visual only). In two further conditions, we tested whether children could maintain an asymmetrical rhythm (2 circles with one, and 3 with the other hand) when visual feedback was veridical or modified to appear symmetrical.

Whereas performance was adequate during symmetric coordination after 5 years of age when proprioceptive information was available, it was not improved by adding visual information. Performance with vision alone was markedly impaired compared to proprioceptive conditions for the younger groups. Moreover, asymmetrical rhythms were not adequately performed even with symmetrical visual feedback.

Our results reveal a lack of visual-proprioceptive integration in children that contrasts with the dedicated use of vision for motor control in adults. This result suggests that the development of multisensory integration for motor control may continue well into adolescence.

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S5.4 Influence of stored body representations on multisensory integration Jared Medina*, Yuqi Liu

Department of Psychological and Brain Sciences, University of Delaware

Information from different sensory modalities needs to be combined to make a coherent, multisensory percept. In addition to known principles of optimal integration based on the precision of each modality, prior knowledge from experience may also influence multisensory integration. We review how information from stored representations of the properties of the body also contribute to multisensory integration, using examples from the mirror box illusion. Over multiple experiments, we presented participants with variants of the mirror box illusion in which the participant's limbs are positioned in opposing postures. After synchronous bimanual movement, participants report an illusory rotation of their hidden hand, such that they feel like it is in the viewed (mirror) position. First, even though participants did not rotate their hands, the illusion was strongly modulated by stored knowledge regarding biomechanical constraints of the body. Second, we examined whether there is differential weighting, not only for different modalities, but information from different types of representations. We found more integration for congruent movements in externally-based versus motor-based frames of reference. Third, examining the time course of this illusion, we found that evidence for two different mechanisms for multisensory integration of the body - immediate visual capture of perceived limb position, or a gradual shift from the proprioceptively-defined to the visually-defined limb position. We discuss how prior information from body representations can be incorporated into existing models of multisensory integration.

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S5.5 Body size perception in healthy adults can be manipulated using galvanic vestibular stimulation and distorted visual exposure Sarah D'Amour*, Deborah Alexe, Isabella Lim and Laurence R. Harris Centre for Vision Research, York University

The brain has an implicit, internal representation of the body that is maintained, adjusted, and updated in response to changes in body shape during growth and development. Here, we investigated how perceived body size accuracy may be affected when body representation is manipulated. We attempted to alter body perception by either having participants look at a distorted image of their own body for five minutes or by the use of disruptive galvanic vestibular stimulation (dGVS sum of sines). Participants were tested with the body or body parts presented in different viewpoints to see if performance changed for familiar and unfamiliar views. The Body Shape Questionnaire (Cooper et al., 1986) was also administered. Accuracy was measured using a novel psychophysical method for determining perceived body size that taps into the implicit body representation (D'Amour and Harris, 2017). The time course of visual adaptation effects was measured. Control experiments were also carried out using a familiar inanimate object (e.g., a Coke can). Manipulating body representation using both visual and vestibular methods resulted in changes to perceived body size accuracy. These results provide insights into how the brain represents the body, revealing that body size perception is flexible and plastic.

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S5.6 Two flavors of tool embodiment

Luke E. Miller Lyon Neuroscience Research Center

A hallmark feature of the sense of our body is that it is incredibly flexible. Perhaps the most striking example of this is the fact that the brain readily incorporates external objects into the way it represents and controls the body, a group of phenomena collectively referred to as "embodiment". For example, using a tool for only a few minutes extends multisensory body representations underlying both perception (e.g. Miller, et al. 2014) and action (e.g. Cardinali, et al. 2009). "Tool embodiment", as this modulation is often called, has been studied in detail over the last two decades (Martel, et al. 2016). However, there is a second "flavor" of tool embodiment that has received far less attention'the user's ability to use a tool as a functional extension of their body. Here, we investigated whether the nervous system treats a tool as a sensory extension of the body. Using a classic tactile localization paradigm, we found that users can sense where an object contacts the surface of a wooden rod with surprising accuracy, just as is possible on the skin itself. Follow-up experiments showed that: (1) this sensory ability does not require prior experience with the rod; (2) the ability to predict the vibratory dynamics of the rod is crucial; (3) users can flexibly update their sensing behaviour to wield novel tools; and (4) the tool (like the body) is represented in both egocentric and tool-centred spatial reference frames. Future research in our lab will investigate how both flavours of embodiment are related. Doing so will provide a more complete picture of how embodiment emerges from the functional coupling between technological and neural levels of information processing. Return to top

Symposium 6 – Multisensory Integration and Aging

June 16th, 10:45am – 12:00pm

Organizer: Jeannette R. Mahoney, Albert Einstein College of Medicine

The ability to successfully integrate simultaneous information relayed across multiple sensory systems is an integral aspect of daily functioning. Unisensory impairments have been individually linked to slower gait, functional decline, increased risks of falls, cognitive decline, and worse quality of life in the elderly. To date, however, relatively few studies have set out to determine how multisensory integration processes change with increasing age. In what follows, we will discuss recent aging work investigating: 1) the temporal binding window of integration; 2) susceptibility to the sound-induced flash illusion; and 3) differential visual-somatosensory integration effects. Our overall objective is to demonstrate the clinical-translational value of multisensory integration effects in predicting important motor outcomes like balance and falls.

S6.1 Temporal Integration of Multisensory Events in Later Years

Michael Barnett-Cowan University of Waterloo

To safely interact with the environment, the brain must guickly make sense of converging multisensory information in order to form a reliable and accurate percept with which to guide decision-making and behaviour. As we age, however, natural changes occurring in the brain affect the way the senses provide accurate and reliable information about the world in timely fashion. While it is well understood that the senses become less sharp as we age, how the brain continues to integrate multisensory cues with unreliable sensory information available in later life is less clear. Older adults have trouble separating multisensory events in time, an observation that cannot be entirely accounted for by an age-related reduction in unisensory detection thresholds, potentially explaining why many sensoryrelated challenges experienced in later life (e.g., decision-making, communication, balance control) persist despite the use of corrective devices designed to address unisensory loss. Given that sensory-related challenges in the elderly can dramatically affect later life functional independence, lead to isolation, impaired communication, and increased fall rates, a shift in the paradigm for assessing and treating sensory impairment in the elderly is needed. Here I review work in our lab that has shown that i) older adults have an extended temporal binding window compared to younger adults, but which is task-specific, ii) older adults are less aware of the perceived onset of a fall compared to younger adults, and iii) the

representation of the duration of multisensory events during a fall is distorted during a fall, particularly for older adults. These results and future work will be discussed in the context of informing falls prevention strategies to help prevent falls in later life.

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S6.2 Simultaneity and temporal order judgments are coded differently and change with age: an event-related potential study

Aysha Basharat*, Meaghan S. Adams, W. Richard Staines, Michael Barnett-Cowan University of Waterloo

Multisensory integration is required for a number of tasks of daily living where the inability to accurately identify simultaneity and temporality of multisensory events results in errors in judgment and can lead to poor decision-making and dangerous behaviour. Previously, our lab discovered that older adults exhibited impaired timing of audiovisual events, particularly when making temporal order judgments (TOJ). Simultaneity judgments (SJ) however were preserved across the lifespan. Recently, we investigated the difference between the TOJ and SJ tasks in younger and older adults to assess neural processing differences between the two tasks and across the lifespan. Event related potentials (ERPs) were studied to determine between-task and between-age differences. Results revealed task specific differences in perceiving simultaneity and temporal order, suggesting that each task may be subserved via different neural mechanisms. The auditory N1 and visual P1 ERP amplitudes confirmed that unisensory processing of audiovisual stimuli did not differ between the two tasks within both younger and older groups, indicating that performance differences between tasks arise either from multisensory integration or higher-level decision-making. Compared to younger adults, older adults showed a sustained higher auditory N1 ERP amplitude response across SOAs, suggestive of an extended temporal binding window. Our work provides compelling evidence that different neural mechanisms subserve the SJ and TOJ tasks and that simultaneity and temporal order perception are coded differently and change with age.

S6.3 A population study of multisensory perception in middle-aged and older adults: The Sound-Induced Flash Illusion in The Irish Longitudinal Study on Ageing (TILDA)

Annalisa Setti*, Belinda Hernández, Rose Anne Kenny, Fiona N. Newell University College Cork

Population studies such as the Berlin Ageing Study and the Health and Retirement Study have provided strong evidence for the link between sensory perception and ageing. Emerging evidence from the experimental literature shows that multisensory perception also changes with ageing, and it is associated with an enlarged temporal window of integration between visual and auditory inputs. A test emerging as robust indicator of such agerelated changes is the Sound-Induced Flash Illusion. Older adults are more susceptible to this illusion over larger stimulus onset asynchronies; this higher susceptibility is, in turn, associated with cognitive and functional disabilities. While multisensory perception has been vastly studied experimentally, there are currently no population data available. Here we present the protocol for the introduction of the Sound-Induced Flash Illusion in the Irish Longitudinal Study on Ageing, a population representative study of 50+ in Ireland. Data on the Sound-Induced Flash Illusion on a sample of 4000 individuals, showing the association between susceptibility at different stimulus onset asynchronies and ageing, will be discussed in light of the experimental literature and the potential contribution of population-level data on multisensory perception to the study of healthy and pathological ageing.

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S6.4 Intra- and inter-individual differences in susceptibility to the Sound-Induced Flash illusion

Jason Chan* & Annalisa Setti University College Cork

The Sound-Induced Flash illusion (SIFI) is a robust multisensory phenomenon occurring when one visual stimulus, for example a flash, is perceived as two flashes when paired with two auditory stimuli in close temporal proximity. Older adults are more susceptible to this illusion than younger adults at longer stimulus on-set asynchronies (SOAs). However, differences in the susceptibility to the illusion occur depending on the population considered (e.g. fallers or active older people who exercise) and on the experimental context (e.g, the number of SOAs) available to the participants during the task. Given that previous research has shown that older adults are a heterogeneous population, these individual differences need to be considered. The SIFI could be potentially part of a non-verbal diagnostic toolkit to assess multisensory integration, however operational standards need to be considered. Furthermore, many studies have used the SIFi to investigate multisensory temporal integration, largely showing the same pattern of results. However, the number of perceived illusions vary between these studies. We will discuss work that shows changing the number of SOAs presented will affect the number of perceived illusions. This suggests the SOAs are modulating the perceived illusion. We will discuss these intra and inter-individual differences in light of temporal integration deficits and prospective use of SIFI to assess such deficits.

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S6.5 Understanding Differential Visual-Somatosensory Integration Effects in Aging

Jeannette R. Mahoney* Albert Einstein College of Medicine

Successful integration of concurrent information across multiple sensory modalities is crucial for functioning in the real world, completion of activities of daily living, and mobility. Yet, research investigating age-related changes in multisensory integration (MSI) processes still remains scarce. To date, there has been converging evidence for larger behavioral MSI effects in older compared to younger adults; however, the question of whether "larger" effects are actually "better" for seniors remains largely unanswered. Findings from our recent visual-somatosensory (VS) multisensory studies provide support for differential patterns of multisensory processing in aging that are associated with static balance, falls, and physical activities. In an attempt to identify potential mechanisms behind these age-related VS integrative effects, we investigated constituent unisensory visual and somatosensory functioning. Results revealed that older adults with poor somatosensory sensitivity demonstrated larger VS integrative effects; however, the largest VS integrative effects were found in seniors with both poor somatosensory sensitivity and poor visual acuity. Collectively, these results shed light on the idea that VS integration is likely a compensatory process used to overcome age-related physiological declines in unisensory processing. While the effect of MSI has been attributed to basic degenerative changes in neuronal architecture during the aging process, this speculative interpretation has yet to be empirically tested. Future studies are clearly needed to establish the structural and functional correlates of multisensory integration in aging, specifically visualsomatosensory integration, in order to further establish the link between differential MSI effects with other important age-related clinical motor outcomes.

Talk Session 2 – Audio-visual substitutions and illusions

June 16th, 1:30pm – 3:15pm

T2.1 Training-induced plasticity with a visual-to-auditory conversion system. Seeing the thunder while still hearing it.

Malika Auvray CNRS – ISIR

William James made the hypothesis that, if our eyes were connected to the auditory brain areas, and our ears to the visual brain areas, we would Ohear the lightning and see the thunderO [1]. Research suggests that modality-specific brain areas, such as the visual cortex, can process auditory stimuli, for instance in the case of brain alteration (e.g., rewired ferret's brain) or sensory deprivation (e.g., blindness). The study we conducted aimed at investigating behaviourally this question, by using a non-invasive technique of sensory plasticity. The participants learned to use a visual-to-auditory sensory substitution device, which translates visual images recorded by a camera into soundscapes. Both before and after training, they completed a Stroop-like task in which they had to recognize soundscapes while being simultaneously presented with task-irrelevant visual lines. Before training, the visual images did not influence the participants' responses. However, after training, they disturbed the participants' response when the auditory soundscape did not correspond to the conversion of the visual image. This visual interference effect reveals that visual imagery can be associated to auditory stimuli. In addition, the participants' performance during training for localisation and recognition tasks, as well as their associated phenomenology, depended on their auditory abilities, revealing that processing finds its roots in the input sensory modality. Our results bring behavioural evidence to the thesis that experience with sensory substitution devices is neither strictly visual nor auditory, but the functional plasticity at stake is complex, and based on a multisensory architecture [2]. Altogether, they suggest that brain plasticity allows people to see the thunder while still hearing it.

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T2.2 Face and line-orientation discrimination via sensory substitution and their brain dynamics in the congenitally blind *Micah Murray*

University Hospital Center and University of Lausanne

Computations within many brain regions (and their perceptual consequences) are independent of the specific sensory information input they receive. This has been demonstrated in visually-impaired and blind individuals using sensory substitution devices (SSDs). Following training, nominally visual processes of face and letter discrimination can be performed within the fusiform face area (FFA) and the visual wordform area, respectively, via exclusively auditory inputs. Such evidence has hitherto come primarily from fMRI, thus leaving the brain dynamics, and so the cognitive mechanisms, of SSD-driven perceptions unresolved. Furthermore, it is unclear if SSDs can achieve computations ascribed to neurons within the primary visual cortex (V1), such as line-orientation discrimination. We recorded 64-channel EEG from nine adult blind individuals (8 congenitally blind, 1 blind from 1 year of age). All participants trained for ~70 hours with the vOICe visual-to-auditory SSD, and none had prior SSD experience. For the EEG experiment, participants were presented passively with soundscapes of letters, line drawings of faces, and their scrambled counterparts, after having behaviourally demonstrated >95% accuracy in discriminating these categories. First, ERPs to face soundscapes differed from those to scrambled faces within the first 400ms post-soundscape onset and involved stronger sources within the FFA and anterior temporal cortices. Crucially, responses to soundscapes of letters with a predominantly horizontal versus vertical line orientation differed first at 270-400ms post-soundscape onset and within V1 and surrounding visual cortices. Orientation discrimination with SSDs is indeed performed in V1. These collective results provide the first demonstration of the dynamics with which highly-tuned Osensory-specificO neural populations perform stimulus discrimination based on inputs from another sense. On the one hand, our findings extend models positing task-contingent brain organization to include V1. On the other hand, our findings impact designs of SSD technologies and the kinds and speed of visual processing that may be achieved.

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T2.3 Noise, multisensory integration, and previous response in perceptual disambiguation

Cesare Parise Oculus Research

Sensory information about the state of the world is generally ambiguous. Understanding how the nervous system resolves such ambiguities to infer the actual state of the world is a central quest for sensory neuroscience. However, the computational principles of perceptual disambiguation are still

poorly understood: What drives perceptual decision-making between multiple equally valid solutions? Here we investigate how humans gather and combine sensory information within and across modalities to disambiguate motion perception in an ambiguous audiovisual display, where two moving stimuli could appear as either streaming through, or bouncing off each other. By combining psychophysical classification tasks with reverse correlation analyses, we identified the particular spatiotemporal stimulus patterns that elicit a stream or a bounce percept, respectively. From that, we developed and tested a computational model for uni- and multi-sensory perceptual disambiguation that tightly replicates human performance. Specifically, disambiguation relies on knowledge of prototypical bouncing events that contain characteristic patterns of motion energy in the dynamic visual display. Next, the visual information is linearly integrated with auditory cues and prior knowledge about the history of recent perceptual interpretations. What is more, we demonstrate that perceptual decision-making with ambiguous displays is systematically driven by noise, whose random patterns not only promote alternation, but also provide signal-like information that biases perception in highly predictable fashion.

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T2.4 Temporal context effects in the McGurk illusion

Lars T Boenke Leibniz Institute for Neurobiology, Magdeburg, Germany

In a typical experiment investigating the McGurk illusion stimuli are chosen in a way that congruent stimuli (template) and incongruent stimuli (competing-incongruent stimulus, CIS) are not competing for the same perceptual category within a single experimental session. This is to avoid that subjects exploit the temporal proximity of template and CIS to tell their difference, thereby degrading the strength or frequency of occurrence of the illusion. Here, we explicitly address the dynamics of the McGurk illusion in a scenario where template and CIS both typically mediate an auditory 'ta' perception (e.g., congruent: visual: 'ta'/auditory: 'ta' and incongruent: visual: 'ka'/auditory: 'pa' both yielding reported 'ta'-percepts). To this end, we presented template and CIS in a single experimental session and randomized order. Post-hoc we sorted the presented trials based on stimulus type and run length (i.e., the number of times the same stimulus occurred in immediate succession). By this analysis we were able to test the frequency of the McGurk illusion as a function of run length of the CIS (which also correlates to elapsed time). Results showed that when the CIS followed the template immediately, the McGurk illusion was indeed less frequent compared to a baseline. This is in line with the (implicit) belief that individuals can exploit the temporal proximity of template and CIS to tell the

difference between the congruent and incongruent stimulus. Further analysis also showed that with increasing temporal distance of the CIS to the template the frequency of occurrence of the illusion approached baseline again.

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T2.5 A new psychophysical paradigm to quantitatively assess body ownership in the rubber hand illusion paradigm.

Marie Chancel Karolinska Institue

The perception of limbs as one's own is called body ownership (BO). BO requires the integration of signals from multiple sensory modalities including vision, touch and proprioception (Ehrsson, 2012). Yet, the literature lacks a sensitive and rigorous psychophysics method to register BO. To fill this gap we developed a new discrimination task that allows a more precise and direct measurement of BO based on a version of the Rubber Hand Illusion (RHI).

In this paradigm, the participants' right hand lies hidden beneath a table, while on this table two identical right RHs are placed in parallel to each other (same distance from the real hand, same orientation). Three robot arms repeatedly apply taps to the two RHs and to the participants' real hand. Each RH can be touched synchronously with the other RH and the participants' hand or with a systematically variable delay (<200 ms, the longer the delay the weaker the BO for that RH). The participants then have to decide which of the two hands feels more like theirs. We manipulated the real hand position's relatively to the RHs (Exp1) and the texture congruency between the visual and tactile stimuli (Exp2).

The results show that participants' perception of BO can be quantitatively described by the mean and variance of the fitted psychometric curves. This fitting does not work under conditions known to abolish the RHI. By analysing the curves' means under different distance conditions, we reproduced well-known constrains of the RHI and, thus, were able to confirm that our paradigm adequately registers BO (Exp1). Moreover, even small discrepancies between the seen and felt touches leads to a significant change in BO (Exp2), which demonstrates the sensitivity of our method. Taken together, our results suggest that BO constitutes a genuine perceptual multisensory phenomenon that can be quantified with psychophysics.

T2.6 Spatial multisensory recalibration operates over distinct timescales David Watson

University of Nottingham, UK

Dynamic changes in the environment require the human perceptual system to flexibly recalibrate the integration of multi-sensory inputs. In the ventriloquism aftereffect (VAE), repeated presentations of spatially discrepant visual and auditory stimuli lead to a perceptual recalibration of auditory space, shifting the perceived location of subsequently presented auditory stimuli in the direction of the visual offset. Yet the timescales over which spatial multisensory recalibration develops remains unclear. Here we characterise the dynamics of the VAE and ask whether they reflect a single adapting mechanism, or multiple mechanisms operating over distinct timescales. We adapted subjects to a sequence of pink noise bursts positioned across a range of azimuths, each presented in synchrony with a Gaussian blob positioned at either the same location, or offset to the left or right by 20 degrees. After each adapting period, subjects reproduced the perceived location of a series of unimodally presented auditory stimuli. We measured the growth and decay of the VAE after adaptation to audio-visual spatial discrepancies for varying durations of adaptation – from 32 up to 256 seconds. Our results showed that the VAE built up and decayed in a manner proportional to the duration of the initial adaptation period. To distinguish recalibration mechanisms operating at unitary or distinct timescale(s), we employed an adapt/de-adapt paradigm. Subjects initially adapted to an audio-visual spatial offset lasting 256 seconds, then immediately de-adapted to the opposite offset for 32 seconds. VAEs elicited by adaptation were initially cancelled by de-adaptation, but subsequently reappeared with further testing. This suggests that opposing VAEs can be simultaneously stored at different timescales. Taken together, our results support a model in which the VAE is governed by multiple spatial recalibration mechanisms tuned to different timescales.

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T2.7 Retiring the McGurk Effect

Lawrence Rosenblum University of California, Riverside

The McGurk Effect has arguably been one of the most influential phenomena in the history of perceptual psychology. In ostensibly demonstrating the automaticity with which the senses combine, it has help motivate a new understanding of perceptual experience and neuroscience as being supremely multisensory. However, the McGurk Effect has also been used as a methodological tool to establish when and how audiovisual integration occurs. The effect has also been used to evaluate how the processes of multisensory integration might differ across individuals, cultures, development, and attentional states.

In this talk, it will be argued that based on what is now known of the McGurk effect, as well as of perceptual and neurophysiological research, the effect fails as a reliable tool for measuring integration. There are clear empirical examples in which the McGurk effect fails, but audiovisual speech integration still occurs (e.g., Brancazio & Miller, 2005; MacDonald, Andersen, & Bachmann, 2000). Other examples show that despite overt responses reflecting no McGurk Effect integration, covert responses show otherwise (e.g., Gentilucci & Cattaneo, 2005; Sato, et al. 2010). It could very well be that given sufficient crossmodal information for a coherent event, integration always occurs, even when McGurk effect responses fail. It will be argued that other measures, including analyses of production responses, as well as simple evaluations of visual enhancement of speech in noise, are more reliable and informative measures of perceptual integration.

Talk Session 3 – Developmental Perspectives

June 16th, 1:30pm – 3:15pm

T3.1 Quantifying the weights of multisensory influences on postural control across development

Mark A. Schmuckler University of Toronto Scarborough

Balance control is fundamentally a multisensory process. Starting in infancy, people are sensitive to a variety of perceptual inputs for controlling balance, including the proprioceptive and kinesthetic inputs traditionally believed to control balance, along with both visual (e.g., presence versus absence of visual input, imposed optic flow information) and haptic (e.g., light-fingertip contact) information. Given such findings, one of the principal questions now facing researchers interested in posture involves quantifying the weighting, and potential reweighting, of sensory inputs across varying task environments, and across developmental time. Work in my laboratory over the years has explored the impact of a variety of such sensory components in different task environments, such as lit versus dark environments, moving room paradigms, varying conditions of haptic input, proprioceptive inputs via explicit manipulations of length and width of base of support, in children ranging in age from 3 to 9 years. The current talk focuses on recent work that has aggregated the findings across these multiple experiments, using these data to specifically address the issue of weighting of varying sensory inputs for postural control, and how this weighting might change over time. Specifically, quantification of sensory inputs was calculated by predicting measures of postural stability as a function of dummy coding for a range of visual, haptic, and proprioceptive inputs. These analyses revealed interesting developmental differences of the relative weights of sensory information across children ranging in age from 3 to 9 years, and adults. Such modeling thus enables the quantification of developmental trajectories in children's relative use of varying visual, haptic, and proprioceptive inputs in postural control.

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T3.2 Infant learning in vision and beyond

Chia-huei Tseng Research Institute of Electrical Communication, Tohoku University

Learning in a multisensory world is challenging as the information from different sensory dimensions may be inconsistent and confusing. By

adulthood, learners optimally integrate bimodal (e.g. audio-visual, AV) stimulation by both low-level (e.g. temporal synchrony) and high-level (e.g. semantic congruency) properties of the stimuli to boost learning outcomes. However, it is unclear how this capacity emerges and develops. One of the challenges comes from the lack of proper research paradigm for infants. To approach this question, we designed a novel paradigm to examine whether preverbal infants were capable of utilizing high-level properties with grammar-like rule acquisition. In this paradigm, we first habituate infants with an audio-visual bimodal temporal sequence that represents an A-A-B rule. The audio-visual relevance and consistence can vary in perceptual (e.g. visual motion and arising auditory frequency), cognitive (e.g. syllables), or semantic dimensions (e.g. emotional categories). I will describe the design rationale, and how our results show that similar to adults, preverbal infants' learning is influenced by a high-level multisensory integration gating system, pointing to a perceptual origin of bimodal learning advantage that was not previously acknowledged.

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T3.3 Crossmodal association of auditory and visual material properties in infants

Yuta Ujiie Research and Development Initiative, Chuo University, Tokyo, Japan

The human perceptual system enables to extract visual properties of an object's material from auditory information. The neural basis underlying such multisensory association has been revealed to develop throughout experience of exposure to a material, by neuroimaging studies in monkey. In humans, however, the development of this neural representation remains poorly understood. Therefore, we addressed this guestion by using nearinfrared spectroscopy (NIRS), a functional brain activity imaging technique, to examine the brain activity in response to audiovisual material matching in 4- to 8-month-old infants. In this presentation, I will show our finding that, in preverbal 4- to 8-month-old infants, the presence of a mapping of the auditory material property with visual material in the right temporal region. This indicated that audiovisual material information involves a relatively high-order processing that is enveloped by the sound symbolism. Also, I will suggest the possibility that the development of the association of multisensory material properties may depend on the material's familiarity during the first half year of life.

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T3.4 Visual and somatosensory hand representation through development. Lucilla Cardinali

Fondazione Istituto Italiano di Tecnologia, U-VIP _ Unit for Visually Impaired People, Genova, Italia

Our body changes in size and shape throughout life. Childhood is a crucial period during which body growth increases substantially. How does the brain keep track of such changes? How visual and somatosensory information is used to create an accurate representation the body? Here we investigate the accuracy of the hand representation in children using a visual and a haptic task. 80 children between 5 and 10 years old judged the size of their own hand against a series of fake hands presented either visually or haptically. Using a staircase method, we found that all children underestimate the size of their hand. The amount of underestimation increases with age and is modality independent, that is, is present for both the visual and haptic task. The variability in the response is higher in the haptic condition compared to the visual one. Finally, the representation bias is body-specific as it is not present when the same children estimated (visually or haptically) objects size. Distortions in hand representations have been previously reported in adults; however, this is the first study to show the presence of a distortion in hand representation in children too. Crucially such underestimation is smaller than the one previously described in adults suggesting that the gap between real body and represented body increases throughout life.

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T3.5 The role of allocentric information in the development of spatial navigation across childhood

Luigi F. Cuturi Istituto Italiano di Tecnologia

The triangle completion task is a navigational and path integration task often used to study the integration of spatial navigation abilities with multisensory cues in order to build an allocentric representation of space. This methodology allows to investigate the capability of updating own position in space relative to the available sensory cues. Here, we tested children (age: 6-11 y.o.) with a triangle completion task to study how well they accomplish spatial updating after turning angles of 45₁, 90₁ or 135₁ to the right or left. Additionally we also tested how an allocentric reference (an auditory cue) might influence performance. Trajectories were recorded by means of the Kinect (motion sensing device – Microsoft) and the EyesWeb platform (Volpe et al., 2016). After walking along the first two legs that compose the triangle (150 cm and 220 cm long, respectively) by being guided by the experimenter, blindfolded participants were asked to return to

the start position without support thus completing the triangle, i.e. along the third leg. Each turn was verbally signaled and indicated by gently pushing the participant towards the target direction. The task was described with a forest exploration narrative in order to make it enjoyable for children. Our results show that younger children performed worse than older peers, thus indicating the role of the developmental stage in understanding the turned angle. In particular, indexes as the distance between the ending point of the trajectory and how stable children maintain a straight heading while moving (i.e. directness), show that performance is worse at the early stages of development (age 6-8 y.o.). The development of spatial updating skills across the lifespan throws light on the ability of discriminating angles by walking and how the integration of external cues could be used to develop a learning platform for teaching angles by walking.

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T3.6 Sensory dominance and multisensory integration as screening tools in aging

Pawel J. Matusz

Information Systems Institute at University of Applied Sciences Western Switzerland (HES-SO Valais)

Naturalistic environments are inherently multisensory and the advantages of multisensory information for brain and behavioural processing are wellestablished. In turn, healthy aging has a pervasive impact on the brain's structure and function, and sensory, perceptual, as well as memory and executive functions seem particularly impacted by aging-related changes. However, these insights emerge from almost exclusively unisensory literature, while the multisensory benefits for information processing are typically enhanced in healthy older compared to healthy younger individuals. These contradictory results could potentially be reconciled by studying sensory-dominance patterns; their importance for multisensory benefits has been shown across the lifespan and changes therein would be consistent with healthy and neurodegenerative aging-related changes in the brain. Thus, we compared healthy young (HY), healthy older (HO) and mildcognitive impairment (MCI) individuals on a simple audio-visual detection task. Neuropsychological tests assessed individuals' learning and memory impairments. First, patterns of sensory dominance emerged only for healthy and abnormal aging groups, towards a propensity for auditory-dominant behaviour (i.e., detecting sounds faster than flashes). Notably, multisensory benefits were larger only in healthy older than younger individuals who were visually-dominant. Second, the multisensory detection task offered added benefits as a time- and resource-economic MCI screening tool. Specifically, a receiver operating characteristic (ROC) analysis demonstrated that a correct MCI diagnosis (derived from the Mini-Mental State Examination,

MMSE) could be reliably achieved based alone on the combination of indices of multisensory integration and of sensory dominance. These results provide much-needed clarification regarding the presence of enhanced multisensory benefits in both healthily and abnormally aging individuals. As such, our findings highlight the potential importance of sensory profiles in determining multisensory benefits in healthy and abnormal aging. Crucially, these results also open an exciting possibility for multisensory detection tasks to be used as a cost-effective complementary screening tool for dementia.

June 16th, 4:45pm – 6:00pm

T4.1 Rapid improvement of audiovisual simultaneity perception after shortterm music training

Karin Petrini Department of Psychology, University of Bath

Several studies have shown that the ability to detect audiovisual simultaneity strongly increases in musicians compared to non-musicians (e.g. Lee and Noppeney, 2011). However, the amount of training required to achieve an improvement in audiovisual simultaneity precision is still unknown. Here we examined whether a short training with a musical instrument would improve audiovisual simultaneity precision in two experiments. In the first one, 13 participants were trained with the drums for two hours, one-hour training session repeated in two separate weeks. Another group of 13 participants passively observed the trainer playing the drums. Before and after the training, or observation, participants were tested on an audiovisual simultaneity judgement task with nine levels of asynchrony and two types of stimuli (a simple flash and beep clip and a more complex face-voice clip). The second experiment was the same as experiment 1 except that 14 participants in the music training group were trained with the saxophone and 15 participants in the control group, who did not receive any training, completed the task at the same time as the music training group. We used an Independent Channels Model to fit the simultaneity judgement data for each participant (Garcia-Perez & Alcala-Quintana, 2012) and obtained measures of model parameters that correspond to sensory (e.g. rate of processing of the visual and auditory cues) and decisional processes (e.g. decision boundary or criterion for asynchrony judgments). We found that active training with the drums significantly improved the precision of both sensory and decisional processes while training with the saxophone only improved one sensory process. These results show a rapid effect of music training on audiovisual simultaneity perception (with the extent of this effect being instrumentdependent), and have important implications for rehabilitation therapies aimed at population with poor audiovisual simultaneity precision (e.g. autistics).

T4.2 The Multisensory Perception of Music

Frank Russo Ryerson University

Definitions of music tend to be unimodal in nature, often including some version of the idea that music is organized sound with aesthetic intent. Even philosophical treatise that attempt to define music in its broadest terms tend to overlook multisensory aspects. However, multisensory aspects abound. Most of the evidence for multisensory integration in music has been derived from audio-visual paradigms, but increasingly research has begun to consider the important role of somatosensation in music. In addition, sensorimotor networks have been implicated that give rise to interesting cascade efcects. For example, spontaneous motor activity in response to rhythm give rise to micro-fluctuations of posture and head position, which may in turn lead to vestibular stimulation. When such motor activity becomes entrained it has the potential to serve as its own channel of sensory input. As such, the perception of music is routinely multisensory, integrating inputs from auditory, visual, somatosensory, vestibular and motor areas. This review will commence with a brief consideration of the auditory-only classical view of music perception with a focus on lateralization, basic modularity, and pathways. The review will then turn to a systematic consideration of evidence regarding non-auditory and multisensory processing of three primary dimensions of music: pitch, timbre, and rhythm. For each dimension, behavioral and neuroscientific evidence will be considered and contextualized with respect to leading theories of multisensory perception.

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T4.3 Tracking the evolution of learning a dance choreography in expert ballet dancers and people with Parkinson's disease Joseph DeSouza York University

At IMRF 2013, we presented analysis on our project examining the neural networks involved in learning a new ballet to a novel piece of music over 8 months with a focus on auditory cortex (DeSouza & Bar 2012). We scanned subjects (expert dancers and people with PD) up to four times using fMRI. To date, we have now scanned 18 professional dancers from the National Ballet of Canada, 12 controls and 10 people with PD. All subjects visualized dancing to a one-minute piece of music during an 8-minute fMRI scan. Subjects were asked to visualize dancing their part while listening to the music. For more details of the training and performances for the first of 4 cohorts (see Bar & DeSouza, 2016). Results revealed a significant increase of BOLD signal, across the sessions in a network of brain regions including

bilateral auditory cortex and supplementary motor cortex (SMA) over the first three imaging sessions, but a reduction in the fourth session at 34-weeks. This reduction in activity was not observed in basal ganglia (caudate nucleus). This increase and decrease in BOLD signal over learning is examined in more depth. Our results suggest that as we learn a complex motor sequence in time to music, neuronal activity increases until performance and then decreases by 34-weeks, possibly a result of overlearning and habit formation. Our findings may also highlight the unique role of basal ganglia regions in the learning of motor sequences. We now aim to use these functional regions of activation as seed regions to explore structural (DTI) and functional connectivity analysis.

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T4.4 Improving visual recognition memory with sound

Arit Glicksohn UCLA

Background: Many objects and events that we encounter in our daily lives produce both visual and auditory information. Previous studies reveal that recognition memory in one modality (e.g., an image of a clock) is enhanced if the object is initially encoded in both modalities (e.g., hearing and seeing a clock). It has been postulated that multisensory encoding results in 'richer' representations, which are later retrieved upon presentation of unisensory information. Question: Is this multisensory encoding advantage limited to natural audio-visual pairings (such as the image and sound of a clock), or does it extend to artificial associations (i.e., objects that are not naturally associated with sound)? Methods: We trained participants to associate a set of geometric patterns with brief melodies, and then tested them in a recognition memory task. In session 1, participants learned the association between shapes and melodies. In session 2, participants performed a memory task consisting of a study phase, delay, and test phase. During the study phase, half of the shapes were presented together with their associated sound, and half were presented in silence, and these trials were interleaved pseudorandomly. During the test phase, all shapes were presented in silence, and the task was to determine for each shape whether it was new or old. Half of the OoldO shapes had been initially presented audio-visually and half presented only visually. Results: Participants were better at recognizing shapes originally encoded audiovisually compared to encoded only visually. Results of a control study confirmed that the association between the shapes and melodies was necessary for the observed enhancement. Conclusion: These findings reveal that multisensory encoding advantage also applies to artificial audiovisual associations, and therefore, associating visual stimuli with sounds can be

exploited to enrich visual encoding, and improve the subsequent retrieval of visual information.

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T4.5 Horizontal variation in visual stimuli affects auditory pitch perception equally in musicians and non-musicians

Jonathan Wilbiks Mount Allison University

When assessing the pitch of auditory tones, participants respond more quickly and more accurately when high pitch is associated with a physically high response key, and low pitch with a low response key (Rusconi et al., 2006). This SMARC effect seems to be relatively universal when it comes to vertical orientation, but there is also evidence for a horizontal SMARC effect in musicians (Keller & Koch, 2008; Cho & Proctor, 2002). Timmers and Li (2017) suggested that since pianists (and to a lesser extent, other musicians) were trained to have a high/right versus low/left spatial representation of pitch because of the way a keyboard is laid out, they exhibit a horizontal SMARC effect as well.

To examine relative effects of auditory and visual factors on the vertical (vSMARC) and horizontal (hSMARC) effects, we employed a 3 (vertical height) x 3 (horizontal placement) x 3 (pitch height) x 3 (horizontal pitch location) design. For each trial, 9 white dots in a 3×3 grid were presented for 1500 ms, then one turned black as a tone, which could be high, medium, or low was presented in left, both, or right ears. Participants were asked to respond to the pitch of the cue by pressing one of three keyboard keys mapped horizontally.

Findings show that horizontal visual cues contribute to perception of pitch height in the expected manner (F(4,164) = 14.75, p < .001). Group comparisons suggest that, while task performance was significantly better in pianists and musicians than in non-musicians (F(2, 41) = 3.7535, p = .03185), pianists unexpectedly show a smaller hSMARC effect than musicians and non-musicians (F(8, 164) = 2.2593, p = .02570). Future research should manipulate factors such as pitch proximity and response mapping in order to provide optimal conditions for hSMARC to be observed. <u>Return to top</u>

Talk Session 5 – Haptics and the Body Schema

June 16th, 4:45pm – 6:00pm

T5.1 Electrophysiological Evidence for the Effect of Tool Use on Visuo-Tactile Integration in Near and Far space

Elena Gherri University of Edinburgh

The representation of the body and the multisensory space near it is modulated by the active use of long tools as suggested by neuropsychological and behavioural evidence in humans. This might suggest that the tools becomes part of the body representation, extending near space into far space. However, little is known about the underlying neural mechanisms and recent studies have suggested that tool-mediated effects on visuo-tactile integration in far space are simply due to the salient tip of the tool which attracts visual attention in far space. Here, we investigate whether the electrophysiological correlates of visuo-tactile integration in near and far space are modulated by active tool use in healthy humans. ERPs elicited by visuo-tactile stimuli in near and far space were measured after short and long tool use. ERPs recorded close to the somatosensory cortex in the P100 time-range were enhanced after long as compared to short tool use. No such modulation was observed over occipital areas where effects of visual attention would be expected, ruling out a role of visual attention in these effect. This pattern of results provides the first electrophysiological evidence that the active use of long tools increased neural activity within somatosensory areas of the brain, in line with the idea of plastic changes to the representation of the body induced by the use of tools.

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T5.2 Influences of Conflicting Visual Information on Body Schema and Haptic Perception of Hands

Katsunori Okajima Yokohama National University

We conducted three experiments to confirm how conflicting visual information modify the body schema where the visual movement was quantitatively incoherent with the actual hand movement in a VR environment. Participants observed their CG hands through a HMD while

repeated opening and closing their hands. We defined Gain which is the ratio of the angle in vision to the angle in hand between thumb and index finger. When Gain is 1, it means the normal (coherence) environment. However, when Gain is not 1, it is an abnormal (incoherent) environment in the relationship between hand motion and visual motion. First, participants repeated opening and closing their hands in an incoherent environment for a few minutes. After that, they adjusted the Gain so as to perceive their hand movements naturally. In Experiment 1, results showed that we can adapt to such a conflicting visual environment in a short period of time and build a new body schema related to the finger joint of both hands. In Experiment 2, we demonstrated that such a multimodal adaptation effect can be transferred between the right and left hands simultaneously, suggesting that a common mechanism for both hands in order to normalize the relationship between the actual hand motion and visual motion of fingers exists in our brains. Finally, in Experiment 3, we showed that the new body schema can also influence the tactile perception while participants estimate the size of a small object by using two fingers after adapting to an incoherent environment between actual hand motion and visual motion of fingers. The results promise that comfortable VR content or new VR interface can be developed by using the plasticity of the human body schema.

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T5.3 The interplay of visual and haptic cues in multisensory grasping Robert Volcic

New York University Abu Dhabi

The target of a grasping action is usually represented in visual coordinates, but it can also be specified by additional haptic cues when we grasp with one hand an object held by the other hand (e.g., reaching for a lid while grasping a jar). In such cases we can plan and execute our actions based on a combination of distance and size cues provided through both vision and haptics. Here, we investigate which of these visual and haptic signals are integrated in multisensory grasping. We contrasted visual and haptic unisensory conditions, and, visuo-haptic conditions in which vision was combined with both haptic distance and haptic shape cues, or, with only haptic distance cues. Participants (n = 20) performed grasping movements toward five differently sized objects located at three egocentric distances. In the visual condition (V), participants had full vision of the object and the workspace. In the haptic condition (H), vision was prevented and the action was under haptic guidance from the other non-grasping hand. In the visuohaptic condition (VH-full), all visual and haptic cues were available throughout the movement. In an additional visuo-haptic condition (VHdistance), participants held a post which supported the object, instead of

holding the object itself, while vision was fully available. In this case, haptics was informative only about the egocentric distance of the object, but not about its size. The availability of both vision and haptics (VH-full) produced faster grasping movements with considerably smaller maximum grip apertures than in the unisensory conditions. Critically, in the VH-distance condition, grasping movements were indistinguishable from those in the VH-full condition. In sum, these findings show that only haptic distance cues in concert with visual signals are needed for optimal multisensory grasping.

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T5.4 Proprioceptive Distance Cues Restore Perfect Size Constancy in Grasping, but Not Perception, When Vision Is Limited

Juan Chen University of Western Ontario

Our brain integrates information from multiple modalities in the control of behavior. When information from one sensory source is compromised, information from another source can compensate for the loss. What is not clear is whether the nature of this multisensory integration and the reweighting of different sources of sensory information are the same across different control systems. Here, we investigated whether proprioceptive distance information (position sense of body parts) can compensate for the loss of visual distance cues that support size constancy in perception (mediated by the ventral visual stream) versus size constancy in grasping (mediated by the dorsal visual stream), in which the real-world size of an object is computed despite changes in viewing distance. We found that there was perfect size constancy in both perception and grasping in a fullviewing condition (lights on, binocular viewing) and that size constancy in both tasks was dramatically disrupted in the restricted-viewing condition (lights off; monocular viewing of the same but luminescent object through a 1-mm pinhole). Importantly, in the restricted-viewing condition, proprioceptive cues about viewing distance originating from the nongrasping limb (experiment 1) or the inclination of the torso and/or the elbow angle of the grasping limb (experiment 2) compensated for the loss of visual distance cues to enable a complete restoration of size constancy in grasping but only a modest improvement of size constancy in perception. This suggests that the weighting of different sources of sensory information varies as a function of the control system being used. Return to top

T5.5 A meaningful pairing between action and the senses Georgiana Juravle

Impact Team, INSERM U1028, CNRS UMR5292, Lyon Neuroscience Research Center, University Claude Bernard Lyon

We present a series of experiments designed to test, in a naturalistic task, how the different senses inform our actions, with the specific goal to investigate meaningful pairings between sensory information and goaldirected actions. Participants were asked to report (with a movement of their choice) how many marbles they believed there were in a jar based on either auditory information only (Experiment 1a) or tactile information only (Experiment 2a). They also estimated marbles numerosities while they searched for a larger marble placed in the jar in half of trials (Experiment 2b). Further, another experiment where all senses were available was performed for both movement tasks (non-meaningful estimate only vs. meaningful search plus estimation, Experiment 3a-b), as well as, in separate experiments, participants gave estimations on the number of marbles based on visual information only (Experiment 4), and passively listening to a recording (Experiment 1b). Overall, participants significantly underestimated the number of marbles in the jar. For low numerosities, results indicated very good estimation performance for visual information, followed by touch, and lastly by audition. Meaningful action improved estimates in audition for higher numerosities, but not in touch. Nevertheless, when examining the movement profiles, meaningful searches based on only tactile information proved to be more ample and consistent as evidenced by higher mean amplitude difference between velocity peaks, higher number of peaks, and higher mean peak velocity. Importantly, as a complement to the substantial behavioural underestimation, movement variability significantly increased for larger marbles numerosities. Our results demonstrate that sensory information intrinsic to the action performed guides goal-directed movement, defines the meaning of our actions, and thus informs cognition.
Symposium 7 – Where is my hand? On the flexibility of multisensory spatial calibration to encode hand positions and movements

June 17th, 9:00am - 10:15am

Organizer: Denise Henriques, York University

The brain can estimate hand position visually, from an image on the retina, and proprioceptively, from sensors in the joints, muscles, and skin. Neither perception is invariant, being subject to changes in lighting, movement history, and other factors. The brain is thought to make best use of available sensory estimates by weighting, aligning, and combining them to form an integrated estimate. Multisensory integration gives us flexibility to cope with the frequent sensory perturbations we experience. For example, when realigning one or both sensory estimates when they become spatially mismatched, as when wearing glasses which induce optical distortions, or when forces are exerted on the hand, including those of gravity. This panel will explore recent experimental and theoretical evidence to better understand how vision, proprioception, and even vestibular information, interact and influence arm-motor control. The panelists represent a broad range of approaches (theoretical, behavioral, neurophysiological), traditions (basic and computational neuroscience, psychology, kinesiology) and hand movement paradigms (2D, 3D, bimanual, unimanual). Yet, their combined work all emphasize how the multiple senses differently and flexibly contribute to the encoding of hand position and movements.

S7.1 Motor cortex effects of recalibrating visuo-proprioceptive estimates of hand position

Hannah J. Block^{*}, Felipe Munoz-Rubke, Jasmine L. Mirdamadi Indiana University

Spatial realignment of visual and proprioceptive estimates of hand position can occur in response to a perturbation. For example, viewing the hand underwater while washing dishes: light refraction by the water shifts the visual estimate of the hand away from the proprioceptive estimate. The brain compensates for such a misalignment by realigning visual and proprioceptive estimates of the hand. Such perceptual learning might be expected to affect the hand perception used in motor planning, raising the question of whether multisensory integration and motor control share a common sensorimotor map. Our recent experiments support this

hypothesis. Using transcranial magnetic stimulation (TMS), we detected excitability changes in the primary motor cortex (M1) index finger representation after subjects experienced misaligned but not veridical visuoproprioceptive information about the index finger (Munoz-Rubke 2017). Interestingly, subjects who realigned proprioception more than vision had decreased M1 excitability, while subjects who realigned vision more than proprioception had increased M1 excitability. This suggests a modalityspecific neural mechanism, such as modulation of somatosensory cortex or dorsal stream visual areas that impact M1. We next asked whether these effects were somatotopically focal. I.e., if misaligned information about the index finger is presented, would changes to M1 excitability be limited to that finger, or extend to the entire effector (including biceps and forearm)? The former might suggest a role for subject's locus of attention (on their misaligned finger position), while the latter might suggest that the brain generalizes perceptual learning to any motor representation that might be involved in finger positioning; i.e., the whole arm. Results support the first option: M1 changes were limited to the misaligned finger representation. These results suggest visuo-proprioceptive realignment is associated with somatotopically focal physiological changes in the motor system, consistent with a common sensorimotor map for multisensory and motor control.

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S7.2 Retention of implicit sensorimotor spatial recalibration

Erin K. Cressman, Stefan Maksimovic, Kristin-Marie Neville, Jean-Michel Bouchard

University of Ottawa

Sensorimotor changes are well documented following reaches with altered visual feedback of the hand. Specifically, reaches are adapted and proprioceptive estimates of felt hand position shifted in the direction of the visual feedback experienced. While motor and sensory changes arise simultaneously, the contribution of proprioceptive recalibration to reach adaptation is unclear. Current research in our lab looks to address this question by establishing the relationship between proprioceptive recalibration and implicit reach adaptation, when reach adaptation due to explicit knowledge and strategies has been accounted for. Within this presentation I will discuss a series of experiments in which we tracked proprioceptive recalibration and implicit reach adaptation over time and examined their potential to be retained in the short- and long-term. Implicit reach adaptation was promoted by manipulating the size of the visuomotor distortion introduced (i.e., error signal experienced by participants) and strategies provided. With respect to sensory changes, results reveal that (1) proprioceptive estimates of hand position develop

over time, though initial changes occur immediately, (2) proprioceptive recalibration is limited in magnitude, such that it does not increase with additional training, and (3) retention of proprioceptive recalibration can be seen in the short- (1 day) and long-term (4 days) in the form of recall and savings, respectively. Implicit reach adaptation is also shown to (1) take time to develop, and (2) be limited in magnitude, such that it does not increase with larger error signals. Finally, (3) retention of implicit reach adaptation experienced.

The similar time course of implicit proprioceptive recalibration and reach adaptation suggest that they are driven by the same slow process. Furthermore, the limited potential of this process to lead to changes in the short and long term, indicate that additional (explicit) processes are primarily responsible for reach adaptation.

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S7.3 Where's my hand? Afferent and efferent signals of hand position in visuomotor adapation.

Denise Henriques, Jennifer Ruttle, Shanaathanan Modchalingam, Chad Vachon and Marius 't Hart York University

Knowing the position of one's limbs is essential for moving and hence it makes sense that several signals provide information on limb position. Apart from vision, we use a predicted position given the efference copy of past movements, as well as afferent proprioceptive information. Both of these have been shown to change when we adapt our movements to altered visual feedback of the hand (i.e., a visuomotor rotation), but how much does each contribute to post-adaptation changes in where we localize our hand? By having participants localize their hand with and without efference signal, we can tease the two contributions apart. Here I will discuss our results investigating the afferent and efferent changes as a function of the size of the visual discrepancy, of the type of training, and of age. Furthermore, I will characterize the time course of the afferent and efferent changes by measuring them after every visuomotor training trial. In summary, we find that 1) active visuomotor training leads to changes in both efference-based predictions and proprioceptive estimates of hand location, but that the change in prediction is smaller that of perception, 2) and this discrepancy was even larger in older adults due to a greater proprioceptive recalibration, 3) passive visual-proprioceptive exposure training led only to changes in hand perception; not prediction. Lastly (4) Proprioception-based changes occur very rapidly, while efference-based contributions come about less rapidly, at about the same rate as motor

changes. These findings imply that proprioceptive changes following visuomotor adaptation are separate from prediction-based changes, with a different process underlying each. This means that the plasticity in our estimates of limb position depends on multiple sources of feedback, and our brains likely take into account the peculiarities of the separate signals to arrive at a robust limb position signal.

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S7.4 Models of visuo-vestibulo-proprioceptive integration for sensorimotor coordination

Joseph McIntyre (Tecnalia Research and Innovation, Ikebasque Research Foundation), Michele Tagliabue (Université Paris Descartes)

In the last decade the application of optimal statistical modelling to understand sensory-motor integration has been very fruitful, allowing a much better understanding on how the CNS uses sensory information to control movements. Guided by these computational models, we have exploited experimental techniques based on virtual reality to probe the workings of the multisensory perceptual system. The combination of experimental and modelling approaches has been very effective for elucidating the origin of a number of behavioural phenomena whose causes were previously unclear.

In a body of completed and on-going studies carried out in Earth-based models of weightlessness, we have exploited these models to better understand how humans combine visual, proprioceptive and graviceptor information when aligning the hand in preparation for grasping an object. We argue for a distributed architecture for the processing of multisensory information in which error signals that drive the hand to the proper alignment are first computed separately in each sensory modality, and then these individual errors are combined in an optimal fashion. This is in contrast to a more conventional conception in which a single, convergent representation of the target is subtracted from a single, convergent representation of the hand. In this symposium we will report our most recent results and collect feedback on experimental paradigms to be performed in the near future on board the International Space Station.

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S7.5 Proprioceptive feedback utilization during visually-guided movements: Impulse vs. limb-target regulation processes *Luc Tremblay, Rachel Goodman, Stephen Bested, Gerome Manson, John de Grosbois University of Toronto*

Clinical cases of significant losses of proprioceptive inputs have reported extremely debilitating effects, indicating an important need for these sensory signals to perform activities of daily living. In addition, many researchers have reported on the important contribution of proprioceptive inputs for the control of voluntary movements towards visual targets. Accordingly, our laboratory has expanded our investigations of visual feedback utilization during movement execution (i.e., online control) to the proprioceptive modality. Our early studies employed tendon vibration manipulations during movement execution, which may have been contaminated by reflexive activity. Therefore, we subsequently leveraged the aftereffects of tendon vibration on Type Ia proprioceptive fibers by applying tendon vibration between trials. When asking participants to perform a limb matching task while being blindfolded, adding tendon vibration between trials yielded increased joint angle variability. Also, applying tendon vibration between upper-limb reaches towards a visual target yields larger trajectory and endpoint variability. In contrast, betweentrial tendon vibration failed to yield significant effects of the proprioceptive manipulation on limb-target regulation processes (e.g., correcting for a target jump). Altogether, our research indicates significant contributions of vision and proprioception to goal-directed actions towards visual targets solely for online impulse regulation processes but not online limb-target regulation processes.

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Symposium 8 – The Multisensory Space – Perception, Neural representation and Navigation

June 17th, 10:30am - 11:45am

Organizer: Daniel Chebat¹ & Shachar Maidenbaum² ¹Ariel University ²Columbia University

We perceive our surrounding environment using all of our senses in parallel, building a rich multisensory representation. This multisensory representation can be used to move through our environment and interact spatially with our surroundings. Vision is the most suited suited sense to assist spatial perception, but how essential is it to the process by which we navigate? And what happen when it is lacking, or unreliable? In this symposium we wish to explore different aspects of this process, and the role of vision and visual experience in guiding this process and the neural correlates thereof. We have put together a strong panel of speakers who have devoted their careers to the study of perceptual and spatial learning, the processing of sensory information and multimodal integration with emphasis on sensory deprivation. Dr Chebat will open, introducing the topic and describing the use of sensory substitution devices to perceive space, amodality, and training induced plastic changes in the brain. He will then be followed by Dr Ptito and Dr Kupers who will discuss anatomical, metabolic and functional changes in the brain of people who are congenitally blind, and the cascade of of resulting changes in the processing of sensory olfactory, tactile and auditory information. Dr Olivier Collignon will then discuss behavioral and brain reorganization linked with sensory deprivation and how this reorganization impacts the perception of space by people who are blind. Dr Maidenbaum will turn from sensory impairment to the use of Virtual Reality tools to manipulate the relative cues between vision, audition and proprioception during navigation and spatial memory tasks. Dr Amedi will close the symposium by discussing a wider theoretical view on these topics with emphasis on brain organization and reorganization arising from sensory impairment and manipulation.

S8.1 The modality independent nature of the human brain's spatial network Daniel Chebat Ariel University

Spatial navigation in the absence of vision has been investigated from a variety of approaches that have progressed our understanding of spatial knowledge acquisition by the blind, including their abilities, strategies, and

corresponding mental representations. Our previous work demonstrated the recruitment of primary visual areas in congenitally blind (CB) individuals, but not in sighted blindfolded or in late blind (LB) individuals, which may enable them to use sensory substitution devices (SSDs) efficiently. Using a combination of functional and anatomical neuroimaging techniques, our recent work has demonstrated the impact of amodal cortical processing in guiding spatial learning. The comparisons of performances between congenitally blind people and sighted people using sensory substitution devices in perceptual and sensory-motor tasks uncovered the striking ability of the brain to rewire itself during perceptual learning and to learn to interpret novel sensory information even during adulthood, not just on congenitally blind individuals, but late blind and even sighted individuals as well. Specifically, we demonstrate that regions that were typically considered "visual" scene selective regions can be recruited through sensory substitution during a navigation task in both congenitally blind and sighted blindfolded counterparts. We argue that scene selective regions and the navigation network in general performs modality-independent spatial computations that does not require visual input to perform spatial tasks.

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S8.2 Structural, metabolic and functional changes in the congenitally blind brain

Ron Kupers and Maurice Ptito BRAINlab, Department of Neuroscience, Panum Institute, University of Copenhagen

For human and non-human primates, vision is one of the most privileged sensory channels used to interact with the outside world. The importance of vision is already strongly embedded in the organization of the primate brain as about one third of its cortical surface is involved in visual functions. It is therefore not surprising that the absence of vision from birth, or the loss of vision later in life, has major consequences for the structural and functional organization of the brain. In this talk, we will first describe a number of brain imaging studies from our lab using (functional) magnetic resonance imaging, diffusion imaging, positron emission tomography and magnetoencephalography that describe some of the structural, metabolic and functional changes that accompany the loss of vision. These studies demonstrate that the absence of vision causes massive structural changes that take place not only in the visually deprived cortex but also in other brain areas. These studies further reveal that the visually deprived cortex becomes responsive to a wide variety of non-visual sensory inputs. Recent studies even showed an important role of the visually-deprived cortex in cognitive and language processes. Next, we will present recent behavioral

studies from our lab indicating that congenitally blind individuals show increases in acuity for tactile, thermal, gustatory and olfactory processes.

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S8.3 Space without sight

Olivier Collignon Institute of Neuroscience (IoNS) of the University of Louvain, Center for Mind/Brain Sciences (CIMeC) at the University of Trento

Vision typically provides the most reliable information about our surrounding space. What happens when you cannot rely on this sensory input due to blindness? I will expose the behavioral and brain reorganizations that occur in blind people for the processing of space. First, I will show that blindness typically triggers enhanced spatial discrimination in the preserved senses and a reorganization of the neural network supporting such abilities. Aside from these quantitative differences, I will also demonstrate that congenitally blind individuals have a qualitatively different way of representing space. Such fundamental qualitative differences in blind people cascade on the way they use space in relation to higher cognitive functions like representing numbers or ordering items in working memory.

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S8.4 Spatial perception and interaction with manipulated sensory reliability Shachar Maidenbaum Columbia University NY

Vision is considered to be the dominant sensory channel which humans use for spatial tasks. However, what happens when this channel clashes with others, e.g. when vision loses reliability compared to other sensory channels like audition, or proprioception?

We explored this via spatial tasks in several virtual environments, which enabled us to control subjects' sensory input and to manipulate the reliability of the visual input. Identical environments were repeated under several conditions: navigating using only audition (via Sensory Substitution), using only vision and in a series of "clash" trials in which the auditory channel was always fully reliable but the visual channel was not. 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 selflearned 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. We then used a head mounted display to explore the effect of matched/mismatched proprioceptive and visual cues, finding that matching significantly boosted reports of immersion but had a smaller effect on task performance. These results demonstrate 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 in both natural and unnatural multisensory conditions.

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S8.5 Task Selectivity as a comprehensive principle for brain organization – including in early sensory region

B. Heimler, S. Hofstetter, S. Maidenbaum, A. Amedi Hebrew University of Jerusalem

In the last decades, convergent evidence from studies with sensory deprived populations such as blind and deaf adults showed that most of the known specialized regions in higher-order 'visual' and 'auditory' cortices maintained their anatomically consistent category-selective properties in the absence of visual/auditory experience when input was provided by other senses carrying category-specific information. In this talk I will explore How early in the visual hierarchy the preservation of visual tasks in other modalities can extend to - Will these include also retinotopic regions, or only higher order ones? Can this plasticity extend even to the earliest regions of the visual pathway such as V1? My main focus will be on the case of early sensory cortices as a model to unravel whether the whole brain is a task-machine or this notion explains only the organization of higher-order sensory cortices. I will present evidence suggesting that early sensory cortices re-organization following sensory deprivation and especially blindness, seems to suggest a negative answer to this question as the deprived V1 has been repeatedly shown to be activated by memory and language (task-switching plasticity). However, I will also present recent data from our lab from navigation tasks in virtual reality demonstrating the functional recruitment for periphery vs. fovea in V1 for non-visual navigation demonstrating task preservation in one of the earliest steps in the visual pathway. Furthermore, i will demonstrate that non visual navigation recruits additional retinotopic regions, such as the dorsal V6 for non-visual navigation regardless of visual experience. These new results challenging this negative conclusion and propose novel ways to conceptualize and test

task-machine organization in those cortices. Finally, I will discuss the implications of our results for both basic research and for clinical rehabilitation settings.

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Poster Session 1 – June 15th 3:15pm – 4:45pm

P1.1 The prevalence of between-hands spatial codes in a tactile Simon task Gherri, E., & Theodoropoulos, N.

University of Edinburgh

When a tactile stimulus is presented to our body, its spatial location is automatically coded, modulating behavioural performance, even when space is completely task-irrelevant (Tactile Simon effect). Here we present a series of studies investigating whether multiple spatial codes are created for the location of tactile stimuli in a tactile Simon task. In the two hands task (Exp. 1 and 3), in which stimuli were presented to one of four possible locations (left and right finger on the left and right hand), the tactile target was automatically coded according to the location of the stimulated hand (between-hands Simon effect) but not according to the location of the stimulated finger (within-hand Simon effect). By contrast, a reliable withinhand Simon effect was observed in the one hand task (Exp. 2 and 3), when tactile stimuli were presented to one of two possible locations on the same hand. Results reveal that tactile stimuli to the fingers are initially encoded relative to their between-hands location. Only when this code is not present or becomes weak, it is possible to observe a within-hand Simon effect. Thus, unlike the visual Simon effect (on the horizontal dimension) in which multiple spatial codes are simultaneously used to encode the locations of stimuli, the tactile Simon effect is primarily based on a single spatial code.

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P1.2 Neural underpinnings of audio-visual integration in the Pip and Pop effect

Fleming, J.T., Noyce, A.L. & Shinn-Cunningham, B.G. Harvard University

During visual search through a dynamic display, reaction times are reduced if a tone is synchronized with changes to a property of a visual target, such as its color. This phenomenon, termed the Pip and Pop effect (Van der Burg et al., 2008), has been demonstrated in multiple behavioral studies, but its neural underpinnings have not been fully explored. In one electroencephalography (EEG) study using a similar paradigm, early multisensory interactions were found most strongly over left visual cortex (Van der Burg et al., 2011). Here, we performed EEG while participants did the original Pip and Pop task, with one of two modifications. In Experiment 1, the synchronous tone could either come from a central loudspeaker – spatially congruent with the visual display – or a lateral speaker at a spatial separation of 90 degrees. In Experiment 2, we manipulated the temporal congruence between the tones and visual target changes. Experiment 1 showed that reaction times improved when a temporally synchronous tone was present, regardless of spatial congruence. In addition, event-related potentials (ERPs) evoked by audio-visual events were significantly enhanced relative to the sum of their unisensory parts. Cluster-based permutation testing revealed that this effect occurred between 100ms and 300ms post-stimulus, with a broad distribution across the scalp. The multisensory enhancement was also significantly stronger for the last audiovisual event preceding target detection as compared to the other stimuli in the trial. Mirroring the behavioral results, these audio-visual effects were present regardless of whether the auditory and visual stimuli were spatially congruent. On the other hand, Experiment 2 demonstrated that reaction time effects were highly sensitive to temporal synchrony, consistent with the effect being subject to temporal windows of audio-visual integration. Taken together, these results demonstrate the key importance of temporal synchrony in facilitating audio-visual integration, with spatial congruence playing a more modest role.

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P1.3 Gender difference of a stroking person influences rubber hand illusion according to autistic traits

Tsuboi, K., Fukui, T. Graduate School of System Design, Tokyo Metropolitan University

The aim of this study is to investigate 1) whether the strength of rubber hand illusion is modulated by a person who is stroking both participant's hand and a fake one synchronously and 2) whether each participant's autistic traits are related to the strength of the illusion. Three conditions were tested: 1) a partner, 2) unknown female, and 3) unknown male stroked a male participant's hand and the rubber hand synchronously. After each condition, proprioceptive drift (PD) and the illusion questionnaire score were recorded. Furthermore, participants were required to answer the Autism Spectrum Quotient (AQ) test before the experiment. No significant differences among three conditions were found in neither PD nor illusion score, although the illusion itself was induced in all conditions. But, we found a significant correlation between illusion score and AQ score in the unknown female condition while no significant correlation was found in the other two conditions. Specifically, higher AQ score was associated with less feeling of ownership over the rubber hand only when a stroking person is unknown female. This result suggests the subjective experience of the feeling of ownership could be modulated by gender of a stroking person and individual autistic traits.

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P1.4 The role of semantic congruency and awareness in spatial ventriloquism

Delong, P. & Noppeney, U. Computational Neuroscience and Cognitive Robotics Centre, University of Birmingham, UK

The extent to which signals from different senses can interact in the absence of awareness is controversial. Models of global workspace predict that unaware signals are confined to processing in low-level sensory areas and thereby are prevented from interacting with signals from other senses in higher order association areas. Previous research has shown that semantically congruent sounds can increase visibility of visual stimuli obliterated from awareness. Here we investigated whether unaware images can influence spatial perception of consciously perceived sounds and whether this spatial ventriloquism could be affected by audio-visual semantic correspondence.

Pairs of semantically congruent or incongruent audio-visual stimuli were presented in spatial ventriloquist paradigm. In the first experiment participants performed simple sound localization. In the second experiment we applied sandwich masking to modulate visual awareness and subjects also reported image visibility and semantic category.

We observed robust modulation of spatial ventriloquism by semantic congruency, but only in the experiment without masking. In the sandwich masking paradigm, sound localization accuracy was still affected by spatial congruency (ventriloquist illusion). However, semantic correspondence did not affect spatial ventriloquism, even for visible trials. At the same time picture identification accuracy and percentage of visible images were significantly higher for semantically congruent stimuli.

These results suggest that audio-visual integration is not affected by semantic correspondence between sound and image, when the latter is not consciously perceived. As in previous studies, we observed an impact of semantic congruency on visual perception, however this could be explained by semantic priming (which has been shown for stimuli within single sensory modality) and not necessarily multisensory interactions. Acknowledgments: This research was funded by the European Research Council (ERC-multsens).

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P1.5 A Pair of Ambiguous Visual Stimuli Improves Auditory Spatial Discrimination

Cappelloni, M.S., Shivkumar, S., Haefner, R.M. & Maddox, R.K. University of Rochester

Studies of the audio-visual ventriloquist effect show that concurrent presentation of a visual and auditory stimulus from nearby locations can lead to visual "capture" of the auditory location. This is typically described as a bias, but possible refinements of auditory localization by a collocated visual stimulus have not typically been the focus of experiments, nor have situations in which there are multiple auditory and visual stimuli. Here we tested both of these notions, with results pointing to a "double ventriloquist effect" in which presentation of two task-uninformative visual stimuli refines the location estimates of two simultaneous auditory stimuli, leading to improved discrimination.

We presented listeners simultaneously with two symmetrically-lateralized auditory stimuli (a tone complex and a pink noise token) and two visual stimuli of per-trial-randomized shape and color that could not be associated with either auditory stimulus, and asked subjects to report the side of the tone. A range of auditory separations was tested, while the visual locations either matched the auditory ones or were both central. Most subjects showed improvements in their auditory spatial discrimination thresholds in the matched visual condition, even though the visual stimuli provided no task-relevant information.

The behavioral data are well fit by a Bayesian model that does not assume exact, but approximate inference. Though we only tested visual stimuli centrally or at the veridical auditory azimuth, the model predicts auditory discrimination could be further improved by visual stimuli at exaggerated azimuths. When visual stimuli are farther apart than auditory stimuli, they also bias the two location estimates in opposite directions away from the midline. This may indicate that in a complex scene, the ventriloquist effect can result in independently biasing the perceived locations of multiple auditory stimuli towards the nearest plausible visual targets.

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P1.6 The Dynamic Double Flash Illusion: Auditory Triggered Replay of Illusory Visual Expansion

Stiles, N R.B., Tanguay Jr., A .R. & Shimojo, S. University of Southern California

In the classic double flash illusion, a real visual flash accompanied by two auditory tones (beeps) is followed by an illusory flash when one beep is simultaneous with the real flash and the other follows shortly thereafter. In particular, when a visual circle is flashed in sync with a beep, and then a second beep is played, an illusory circle is perceived to be flashed in sync with the second beep. The illusory flash has been previously shown to be triggered by the second auditory beep.

Our investigation extends the double flash illusion by showing that not only can an on-off flash be duplicated by this paradigm, but also that an illusory expansion (induced by the flash of a circular brightness gradient) can be triggered to replay when paired with two beeps. We hypothesize that this illusory expansion replay (or dynamic double flash) could be caused by the reactivation of subconscious patterns in early visual cortex generated by recent visual stimuli (similar to Transcranial Magnetic Stimulation (TMS) "replay", but here activated crossmodally by sound). The perception of the dynamic double flash further supports the interpretation of the illusory flash as similar in its spatial and temporal properties to the perception of the real visual flash, in this case by replicating the illusory expansion of the real flash.

In a second experiment, we show further that if a circular gradient stimulus (generating illusory expansion) and a sharp-edged circle are presented simultaneously side-by-side with two beeps, one synchronous with the stimulus and one following, in some cases only one visual stimulus or the other will double flash. This observation indicates that the double flash illusion can be used as a tool to study differential auditory-visual binding by recording whether a given visual stimulus double flashes within a pair of synchronously presented stimuli.

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P1.7 Brightness-mass matchings in adults' reasoning of physical events Sanal, N., Bremner, J.G. & Walker, P. Lancaster University

Previous research suggests that adults make cross-modal matchings between brightness of objects and perceived heaviness. Adults judge darker objects to be heavier in weight than light coloured objects (Walker,

2012). It is unknown whether these matchings are considered in adults' judgements of physical events. Infants first start to make inferences about mass through size and distance relations in simple collision events about 5.5-6.5 months of age (Kotovsky, & Baillargeon, 1998). They anticipate a greater displacement of a standard object after collision with a large object and a lesser displacement after collision with a small object. Given the infant evidence, how adults would reason about the same events is unknown especially if the objects are of same sizes but vary in colour. The present study examined the brightness-mass relationship in 24 adults using 2D computer-animated collision events. Adults were first shown a reference event in which a grey billiard ball (\emptyset =60) rolled down a ramp and hit a grey cube (W= 95, H= 95) to the midpoint of screen. Next, adults saw four test events in random order, a white or black billiard ball (\emptyset =60) moved the grey cube either to before (i.e. a short distance) or after the midpoint (i.e. a longer distance) on the screen. Adults were first asked to rate the test events on how real they were (part A) and later in comparison to the reference event (part B). Adults thought it more likely for the white ball to move the cube a short distance than a longer distance in part A. In part B, adults judged it to be more likely for the white ball to move the cube to a short distance and black ball to move the cube to a longer distance. In conclusion, adults based their judgements solely on the colour of the object.

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P1.8 The rubber hand illusion in merged vision with another person

Okumura, K., Ora, H. & Miyake Y. Department of Computer Science, Tokyo Institute of Technology

Illusions using multisensory modalities have given us important knowledge as to how we perceive our body. The rubber hand illusion (RHI), one of the well-known illusions, has been widely investigated that synchronous tactile stimuli on a person's hidden real hand and an aligned visible rubber hand placed in front of them results in a feeling of ownership of the fake hand. However, the effect of the intensity of visual stimulation on the RHI is not clarified. In this study, we examined whether RHI is elicited by merged firstperson visions of the participants (live) and another (recorded) so as to investigate the effect of the intensity of visual stimuli of the rubber hand and one's own hand. Participants were presented the videos showing their real hands on their right side and the virtual hand of another person to the left of the real hands, which were generated by merging two first-visions through the head-mounted display. The camera was attached to the display to acquire live first-person visions of participants. Then, their right hands were stimulated by a paintbrush synchronized or asynchronized with the strokes on the virtual hand for 150 seconds. The blending ratio of live (participants) to recorded (another person) was 2:8, 5:5 or 8:2. The illusion of ownership was evaluated by questionnaires and proprioceptive drift, the difference between the estimated position of the real hands before and after the stimulation. The RHI was clearly observed only when the blending ratio was 2:8 and touch condition was synchronous, while not much effect was observed in the other conditions. Our results show that if making participants' hands less visible and the virtual hand more visible, the RHI is induced by the combination of the synchronized tactile and visual stimuli of merged first-person visions of the participants and another.

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P1.9 Developmental susceptibility to visuospatial illusions across vision and haptics

Holmes, C.A., Cooney, S.M., & Newell, F.N. Trinity College, University of Dublin

Developmental studies of susceptibility to visuospatial illusions are limited and inconclusive [1], especially those that contrast perception across multiple sensory modalities [2, 3, 4]. Here, we examined spatial perception using three classic illusions - the Ebbinghaus, Muller-Lyer, and Vertical-Horizontal illusions – in which children explored the stimuli across three conditions: visual only, haptic only or bimodal. Specifically, we tested younger (6-8 years) and older children's (9-12 years) ability to discriminate spatial extent in the presence (illusion trials) or absence of illusory contexts (i.e. control trials per illusion consisting of circles, horizontal lines, and vertical lines respectively). Spatial perception in all trial types was tested using a 3-AFC paradigm in which participants were presented with two adjacent stimuli and indicated which of the two was the larger or if both were the same. The results suggest both age groups were susceptible to all three illusions in vision and touch. Visual dominance in the control condition is consistent with previous reports suggesting developmental shifts in multisensory integration for small-scale spatial perception relating to object perception [5], as well as large-scale spatial perception for navigation [6]. Importantly, by examining the effect of modality on visuospatial susceptibility across dimensions, these findings can be used to inform mathematical pedagogy related to geometry in sighted as well as visuallyimpaired populations.

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P1.10 Stimulus parameters underlying sound symbolic crossmodal correspondences

List, S.M., McCormick, K., Lacey, S., Sathian, K. & Nygaard, L.C. Emory University

Humans share consistent associations, known as crossmodal correspondences (CCs), between seemingly unrelated features in different sensory modalities. While one of the fundamental properties of language is the assumed arbitrariness between sound and meaning, sound symbolism is a notable exception that has been studied empirically using CCs between auditory pseudowords (e.g. 'loh-moh') and visual shapes (e.g. blob). Others have investigated auditory-visual CCs and shown that modulating the physical dimensions that define them can influence multisensory integration. However, the characteristics of the auditory and visual stimuli that underpin sound symbolic CCs are not well understood. Here, we used representational similarity analysis to examine the relationships between physical stimulus parameters and perceptual ratings for a range of auditory nonwords (n = 537 stimuli; 31 participants) and visual shapes (n = 90 stimuli; 30 participants), which varied in ratings of roundedness and pointedness. Representational dissimilarity matrices (RDMs) for the perceptual ratings of the auditory and visual stimuli were significantly correlated (r = 0.66, p<0.0001), indicating a close relationship between ratings in the two modalities. In both visual and auditory domains, RDMs of multiple stimulus measures were significantly correlated with RDMs of the perceptual ratings. For instance, the RDM for the fast Fourier transforms of the auditory nonwords, reflecting their spectral composition, was significantly correlated with the RDM of the auditory perceptual ratings (r = 0.28, p<0.001), while the RDM for a measure capturing the spatial profile of the visual shapes, termed the simple matching coefficient, exhibited a significant correlation with the RDM of the visual perceptual ratings (r = 0.28, p<0.001). This research provides insights into the fundamental nature of sound symbolic CCs and how they might evoke specific interpretations of physical meaning in natural language at the physical and perceptual levels.

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P1.11 Electrophysiological evidence for differences between fusion and combination illusions in audiovisual speech perception

Lindborg, A., Baart, M. & Andersen, T. S. Technical University of Denmark

Incongruent audiovisual (AV) speech can cause perceptual illusions such as the McGurk fusion, in which incongruent inputs (such as auditory 'ba' and visual 'ga') are fused to a novel percept (eg. 'da'). However, switching the modality of the cues produces a McGurk combination (i.e. auditory 'ga' and visual 'ba' are perceived as 'bga' or 'gba'). Previous literature has shown differential AV integration patterns for fusion and combination stimuli, suggesting differential processing driving the respective illusions.

We explored whether electroencephalographic (EEG) correlates of audiovisual integration – visual-induced suppression of the auditory N1 and P2 event-related potential (ERP) components – are different for fusion and combination stimuli. We analysed EEG from 32 subjects, comparing the ERPs of the auditory (A) component to the audiovisual minus the visual component (AV-V) for congruent, fusion and combination stimuli.

We found that all AV stimuli suppressed the N1 and the P2 compared to A, and the P2 amplitude was the same for fusions and congruent stimuli. Critically however, P2 suppression was larger for combinations than for congruent stimuli, and the differences between these two types of stimuli extended well beyond the P2.

A possible interpretation of our results is that differences in mismatch processing contribute to the difference between the combination and fusion percept from the P2 and onwards, in line with the observation that fully incongruent AV speech yields a bigger P2 suppression than congruent AV speech (Stekelenburg & Vroomen 2007). Further investigations will have to be made to confirm this interpretation, but it is nevertheless clear that the fusion and combination illusion have distinct electrophysiological signatures.

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P1.12 Auditory feedback effects on spatial learning: shape recognition after audio-motor training

Martolini, C., Cappagli, G., Campus, C. & Gori, M. DIBRIS, University of Genoa - U-VIP, Italian Institute of Technology (Genoa) Recent reports demonstrated that the use of auditory feedback to complement or substitute visual feedback of body movements is effective in conveying spatial information and it can enhance sensorimotor learning. For instance, it has been shown that the curvature of a shape can be conveyed with solely auditory information in sighted individuals (Boyer et al., 2015) and that blind people can recognize objects by extracting shape information from visual-to-auditory sensory substitution soundscapes (Amedi et al., 2007). However, it still remains unclear whether sensorimotor integration might enhance auditory perception.

In the present study, we tested the possibility to improve auditory shape recognition by performing a specific training based on auditory and motor feedback. To assess the effects of the training, we focused on two features related to auditory shapes: semantic meaning and smoothness of contours.

We evaluated a group of sighted adults in two sessions of an auditory shape recognition task, in which each blindfolded participant was asked to identify auditory shapes resulting from the activation of consecutive loudspeakers embedded on a fixed two-dimensional vertical array. Between the sessions, participants performed an audio-motor training, in which they were asked to reproduce a simple (one-joint) or complex (two/three-joints) arm movement initially carried out by the experimenter. The experimenter had an audio source attached to both his wrists, while participants were provided with only one audio source on the dominant wrist as a feedback conveyed by his own movements.

The main findings resulting from preliminary analysis suggest a stronger effect of the training on the semantic meaning factor, compared to the smoothness of contours factor.

Our work suggests that the introduction of combined auditory and motor feedback in a rehabilitative contest might improve cross-modal recalibration and shapes recognition at a cognitive level.

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P1.13 Human echolocators achieve perceptual constancy by discounting variations in click spectrum Norman, L. J. & Thaler, L. Durham University

Perceptual constancy refers to the ability to perceive properties of objects as being stable despite changes in the sensation of those objects caused

by extraneous conditions. Humans primarily use vision for perceiving distal objects, but some people perceive distal objects through the interpretation of sound echoes that the objects reflect - a skill known as echolocation. Human echolocators typically produce tongue clicks in order to do this, but these clicks can vary in their intensity or spectrum, causing extraneous changes in the acoustic properties of echoes reflected from objects. Here we tested whether humans are able to achieve perceptual constancy in echolocation, by testing whether they can discount changes in an object's echo that are brought about by variations in the click. We also considered the effect of echolocation experience in this context by testing expert echolocators as well as newly trained sighed and blind people. On each trial in our task, participants listened to two successive echolocation sounds (i.e. click-echo pairs) through headphones and judged whether the difference in the echoes between the two echolocation sounds was due to a difference in the click emission or a difference in the object that had reflected the sound. For click or object differences carried through spectral changes, blind expert echolocators were able to perform this task well, and much better than sighted and blind people new to echolocation. For differences carried through intensity changes, however, performance in all groups was not much greater than chance. Overall, the data suggest that human echolocators can use spectral information to achieve perceptual constancy for objects across variations in the spectrum of the click emission. This ability depends on the degree of experience using echolocation, implying that perceptual constancy in a novel sensory skill can be acquired through learning.

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P1.14 Occipital early responses to sound localization in expert blind echolocators

Tonelli A., Campus C., & Gori M. Istituto Italiano di Tecnologia

Echolocation is an ability that few blind individuals developed to orient themselves in the environment by using self-generated sounds. In a recent work (Vercillo et al., 2014), it was showed that expert blind echolocators have better sense of auditory spatial representation comparing to congenitally blind individuals and performance similar to sighted people. In the current study, we investigate the neural correlate related to an auditory spatial bisection task in congenital blind, expert and not expert echolocators. We found an early activation (50-90 ms) in the occipital cortex related to sound stimulation just for the group of expert echolocators. Moreover, the early activation in the occipital cortex was contralateral to the position of the sound to localize. Similar results were already found by Campus at al. (2017), in which they show the same activation also in sighted people, for the same task. All these findings candidates echolocation as a good substitute for vision to improve general sense of auditory space, thanks to a process of sensory calibration using sounds.

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P1.15 Rapid, flexible cue combination with augmented and familiar sensory signals

Negen, J., Wen, L., Probert, H., Thaler, L. & Nardini, M. Durham University

Humans are highly effective at dealing with noisy, probabilistic information from multiple sensory systems in familiar settings. One hallmark of this is cue combination: combining two independent noisy sensory estimates to increase precision beyond the best single estimate, taking into account their reliabilities. We will present evidence that this process also occurs in situations akin to common methods for augmented sensory perception, specifically human echolocation and devices translating distance measurements into vibrotactile signals (like the EyeCane). Following just two hours of training with one of the new sensory skills (N=12 each), participants were asked to estimate distances with their new skill, with a noisy visual cue, or with both vision and augmented perception. Participants were more precise given both cues together versus the best single cue, reducing variable error by 16% (echo-like) and 13% (vibrotactile), both pvalues below .001. For the echo-like cue, this persisted when we changed the auditory frequency without feedback (no similar manipulation was done for vibrotactile). In both cases, reliability changes also led to a re-weighting of cues, meeting the predictions of a core principle of Bayesian combination, rather than suggesting use of a decision rule for specific stimuli. These results show that the mature multisensory apparatus can learn to flexibly integrate new skills into its repertoire on a rapid timescale, contrary to both model predictions and previous empirical results with another augmented sensory system (the feelSpace belt). Our results have applications to (1) understanding the role of experience vs maturation during development of cue combination, (2) the use of sensory augmentation to meet clinical needs (e.g. combining a new sensory skill with remaining vision for partial vision loss), as well as (3) enhancing healthy perception in novel ways (for example, a surgeon flexibly combining native sight and augmented hearing as guides).

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P1.16 Multimodal feedback for spatial learning: comparing the effects on sighted and visually impaired individuals.

Cappagli G., Cuppone A.V., & Gori M. Istituto Italiano di Tecnologia

In the last years, the role of multisensory training in spatial learning has been taken into account, e.g. providing evidence that combined multimodal compared to unimodal feedback improves responsiveness to spatial stimuli. To date, it still remains unclear how training conditions influence spatial enhancement and to which extent multisensory training enhance spatial perception in the case of sensory loss. Here we investigated the effects of active and passive audio-motor training on spatial perception in the auditory and proprioceptive domains in sighted and blind participants.

We found that for sighted participants, the passive multimodal training (both auditory and proprioceptive passive movements) is more beneficial than both the active multimodal training (both auditory and proprioceptive active movements) and the unimodal training (only auditory or proprioceptive) and spatial improvement generalizes to the untrained side of the body only when the training is passive. Moreover, we found that the passive multimodal training produces a similar spatial enhancement in blind participants, especially in the proprioceptive domain, indicating that combined sensorimotor signals are effective in recalibrating auditory and proprioceptive spatial perception in the case of visual loss. A possible interpretation of such results is that the perceptual benefit obtained with the multimodal training determines the refinement of coherent audio-motor spatial maps that are necessary to orient body in space.

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P1.17 The early auditory-evoked cortical response predicts auditory speech-in-noise identification and lipreading ability in normal-hearing adults

Dias, J.W., McClaskey, C.M. & Harris, K.C. Medical University of South Carolina

Perceivers suffering from sensory deprivation or loss have been known to recruit more cross-sensory resources when navigating the world, a phenomenon typically associated with cross-sensory neural plasticity (Rosenblum, Dias, & Dorsi, 2016). In the auditory domain, cortical evoked responses, specifically P1 and N1, can be used to assess the timing and efficacy of sensory transmission between the ear and the brain. Reduced amplitudes and increased latencies associated with auditory neuropathy and presbycusis predict degraded auditory perception of both speech and non-speech events (Harris, Wilson, Eckert, & Dubno, 2012; Narne & Vanaja, 2008). However, subtle individual differences in the auditoryevoked responses of normal hearing adults also predict variability in auditory perception (Narne & Vanaja, 2008). We predict that smaller auditory-evoked responses in normal-hearing adults will be associated with better processing of visual information. The current investigation examines the extent to which individual differences in the auditory-evoked response predict auditory and visual speech identification in normal-hearing adults. Eighteen normal-hearing young adults between the ages of 19 and 30 (13 female) participated in this study. P1 and N1 components were extracted from click-induce auditory-evoked responses. Participants identified auditory, visual (lipread), and audiovisual speech within three levels of auditory noise (-5 dB, 0 dB, and +5 dB auditory signal-to-noise ratios). Smaller P1 amplitudes predicted poorer auditory speech identification in the most difficult listening conditions. However, smaller P1 amplitudes also predicted better visual speech identification, suggesting that individuals with smaller auditory-evoked responses may be more proficient lipreaders. Magnetic Resonance Spectroscopy (MRS) and Magnetic Resonance Imaging (MRI) from a subset of participants will be used to explore the neuroanatomical correlates underlying the relationship between the auditory-evoked response and auditory-visual speech processing. Results will be discussed relative to the potential factors affecting auditory-evoked responses and how these factors may contribute to cross-sensory recruitment of visual processes.

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P1.18 Temporal tuning of immediate and repeated exposure to audio-visual spatial discrepancies

Goodliffe, J.P., Roach, N.W. & Webb, B.S. University of Nottingham

Human perception of an external event is typically a coherent multisensory experience. To keep the senses in register, the brain appears to monitor the correspondence of different sensory inputs over different timescales and correct for any discrepancies between them. Exposure to a single spatially

discrepant audio-visual stimulus can lead to the ventriloguist effect (VE), whereby the perceived location of the sound is biased towards the location of the visual stimulus. Repeated exposure to audio-visual stimuli with a consistent spatial offset causes a lasting remapping of auditory space known as the ventriloquist aftereffect (VA). Despite their functional similarity, few studies have systematically compared the characteristics of these effects within the same experiment. Here we examine the temporal tuning of both effects using a common method to measure perceptual bias. Audio-visual stimuli were presented at 15 azimuths over a range of 70 degrees. Visual stimuli were 150ms luminance-defined Gaussian blobs projected onto a wide-field, immersive visual display. Auditory stimuli were 150ms bursts of pink noise, convolved with generic head related transfer functions and reverberant room cues and played through headphones. In VE blocks, audio-visual stimuli were spatially separated by +/- 10 degrees with stimulus onset asynchronies from 0 to 1400ms audio lead. Participants reported their perceived auditory location while ignoring visual stimuli. In VA blocks, participants were repeatedly exposed to consistent spatial and temporal discrepancies (75 pairs) before reporting perceived auditory location on audio-only test trials. Our results show that both tasks produce robust biases in the perceived locations of auditory stimuli. While the VE was consistently larger than the VA with synchronous audio-visual stimuli, both effects decreased with audio-visual asynchrony at a comparable rate. The similar temporal tuning profiles indicates the effects are closely related, either by the VE facilitating the VA, or via co-dependencies with earlier multisensory binding processes.

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P1.19 Audiovisual crossmodal correspondences between bubbles' size and pouring sounds' pitch in carbonated beverages

Roque, J.R., Lafraire, J.L., & Auvray, M.A.

Centre de Recherche Pernod Ricard, France; Center for Food and Hospitality Research, Institut Paul Bocuse, France; Sorbonne Université, UPMC, CNRS, Institut des Systèmes Intelligents et de Robotique (ISIR), F-75005 Paris, France

The literature on crossmodal correspondences has reported an implicit association between auditory pitch and the size of visually-presented circles. However, whether more ecological and complex audiovisual stimuli are stable enough to allow for a pitch-size correspondence effect remains to be investigated. Based on recent studies, two features of carbonated beverages have been selected as the ecological counterparts of the abovementioned pitch and circles. These two features were bubbles' size (small vs. big) and the pitch of a pouring sound of a carbonated beverage (high-

pitched vs. low-pitched). To study a potential crossmodal correspondence between these attributes, a modified version of the Implicit Association Test (IAT) was used. The participants had to respond to four unimodal stimuli that were either visual or auditory, which were paired either congruently (small bubbles and high-pitched sound; big bubbles and low-pitched sounds) or incongruently (the reverse associations). The analysis of the latency and accuracy of the participants' responses confirmed the existence of a pitch-size correspondence effect between these different attributes. A Go/No-go Association Task (GNAT) has subsequently been used to evaluate the relative strengths of these associations, through the analysis of the sensitivity in the participants' responses. Our results highlight the existence of crossmodal correspondences between perceptual features involved in the multisensory experience of carbonated beverages. Since these sensory cues have been reported to influence the perception of freshness, we conclude that these correspondences could be triggered to ease consumers' categorization of a given product as being fresh or even lead to freshness enhancement. Such perceptual mechanisms represent promising levers on the acceptance and appreciation of beverages.

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P1.20 Face Viewing Behavior Predicts Multisensory Gain During Speech Perception

Rennig, J., Wegner-Clemens, K. & Beauchamp, M.S. Baylor College of Medicine

During face viewing, some individuals prefer to fixate the mouth while others fixate the eyes; the consequences of this difference are unknown. During speech perception, viewing the talker's face improves comprehension because mouth movements are associated with speech sounds. Individuals who have a history of mouth fixation might have formed stronger associations between visual and auditory speech, resulting in improved comprehension. To test this idea, we first measured eye movements during a face-viewing task in which mouth movements were unimportant. Replicating previous work, there was substantial interindividual variability in the amount of time participants fixated the mouth, ranging from 11% to 99% of total fixation time. Next, we measured eye movements and comprehension during perception of noisy auditory speech with or without visual speech. When visual speech was present, all participants primarily fixated the mouth (72% to 100% of total time) and derived substantial benefit, recognizing on average 31% more words than for noisy auditory speech alone. However, there was high interindividual variability, with multisensory gain ranging from 6% to 56%. The benefit of visual speech for each participant was predicted by the eye movements made during the

initial face-viewing task (r = 0.44, p = 0.01) but not by eye movements during the noisy speech task (r = 0.05, p = 0.77), an observation confirmed with Bayesian model comparison. Participants who fixated the mouth when it was not important (during the initial face-viewing task) received more benefit from fixating the mouth when it was important (during the noisy speech task). These findings suggest an unexpected link between eye movement behavior during face viewing and audiovisual speech perception and suggests that individual histories of visual exposure shape human abilities across cognitive domains.

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P1.21 Audiovisual recalibration and selective adaptation for vowels and speaker sex

Baart, M. & Vroomen, J. Tilburg University

Humans quickly adapt to variations in the speech signal. Adaptation may surface as recalibration, a learning effect driven by error-minimization between lipread (or lexical) information and the auditory speech signal (e.g., listeners report more /b/-responses to an ambiguous test sound halfway between /b/ and /d/ if the ambiguous sound was previously combined with lipread /b/), or as selective adaptation, a contrastive aftereffect driven by "neural fatigue" of auditory feature detectors (e.g., listeners report fewer /b/responses to the ambiguous test sound if preceded by clear auditory /b/). Here, we examined for the first time if these assimilative and contrastive aftereffects occur for vowels and speaker sex using multidimensional speech sounds. Participants were exposed to videos of a male/female speaker pronouncing /e/ (in the context of beek) or /a/ (in the context of beuk) that were paired with clear or ambiguous vowels of clear (male/female) or androgynous speaker sex. In a subsequent test phase, they then categorized test sounds for vowel identity or speaker sex. With identical adapter stimuli, audiovisual recalibration and selective adaptation could be demonstrated for both vowels and speaker sex.

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P1.22 Crossmodal correspondences between pitch, retinal size, and realworld size

Janini, D. & Konkle, T. Harvard University

Natural crossmodal mappings exist between visual size and auditory pitch: small circles associate with high tones and big circles associate with low tones (Evans and Treisman, 2010). Given proposals that such mappings originate from statistical learning in real-world environments, we first tested the pitch-visual size relationship, and then explored whether this crossmodal relationship extended to the familiar size of real-world objects. In the replication studies, participants judged whether a circle on the screen was big or small (direct task) or judged whether the stripes in the circle were oriented left or right (indirect task), ignoring the high or low tone that preceded circle onset by 150ms. Reaction times were indeed faster when pitch was congruent with circle size, but this effect was only observed for the direct task and was not replicated when the circles were embedded in noise to increase task difficulty. In the extension studies, participants were shown pictures of real-world objects (e.g. paperclip, desk) at the same visual size and responded whether the object was big or small in the world, ignoring the same tone stimuli from the prior studies. We found that reaction times were faster for congruent than incongruent pairings in the direct task, showing this mapping may naturally extend to real-world objects. However, as in the previous studies, the effect was not evident in the indirect task, nor when the images were embedded in noise. Previous researchers have proposed that crossmodal correspondences allow for more accurate estimates of environmental properties in noisy multi-sensory environments (Spence, 2011). Our findings confirm that natural correspondences between pitch, retinal size, and real-world size do exist. However, these correspondences may not be robust enough to guide behavior in noisy realworld settings.

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P1.23 Adapting emotions across the senses: the benefit of congruent over incongruent audiovisual emotional information depends on the visibility of emotional faces

Izen, S.C., Morina, E., Leviyah, X., & Ciaramitaro, V.M. University of Massachusetts Boston

Correctly interpreting the emotional state of others is crucial for social interaction. Often, this involves integrating information across faces and voices. The current study investigated how emotional sounds influence the perception of emotional faces. Although exposure to emotional faces results in an opposite aftereffect, for example, adapting to happy faces biases neutral faces to be perceived as angrier (Rutherford et al., 2008), conflicting evidence exists for how emotional faces and voices interact. Given the principle of inverse effectiveness, that multisensory integration is most

robust when individual stimuli are less effective (Stein & Meredith, 1993), we hypothesized increased multisensory interactions for faces of decreased salience. We quantified adaptation strength as a proxy for the strength of multisensory interactions for emotional faces in noise, decreased in visual salience, versus unedited emotional faces.

Participants judged a series of 8 face identities morphed on a continuum from 80% angry to 80% happy as either happy or angry at baseline and post-adaptation to congruent (100% happy faces and positive sounds) or incongruent (100% happy faces and negative sounds) stimuli. Adapting faces were unedited or embedded in noise. For each participant, we calculated the face morph perceived as neutral, equally likely to be judged happy or angry, and the change in this point of subjective equality (PSE) post-adaptation. We expected greater PSE shift magnitude for congruent versus incongruent emotions, with the greatest shift post-adaptation for faces of decreased salience.

Our results suggest adaptation to congruent and incongruent multimodal stimuli biases neutral faces to be perceived more negatively, with significantly larger shifts following exposure to congruent versus incongruent stimuli, but only for faces in noise. This suggests multisensory integration of emotional information also follows the principle of inverse effectiveness, being more effective for concurrent auditory information of matched valence when faces have diminished perceptual salience.

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P1.24 Naturalistic Stimuli Reveal Selectivity for Eye and Mouth Movements within the Human STS

Zhu, L.L. & Beauchamp, M.S. Baylor College of Medicine

Speech perception is a multisensory process that combines visual information from the talker's face with auditory information from the talker's voice. Posterior temporal cortex, including the superior temporal sulcus (STS) is a key brain locus for multisensory speech perception. Previously, we used BOLD fMRI to demonstrate anatomical specialization within the STS. More anterior regions of the STS preferred visually-presented mouth movements while more posterior regions preferred eye movements. These experiments used only 10 different videos (all recorded in a laboratory setting) a limited stimulus set that is not an accurate representation of everyday visual experience. To examine the generalizability of our results, we created 120 videos of naturalistic mouth and eye movements taken from YouTube. BOLD fMRI data was collected from 16 participants using a

Siemens 3T Prisma scanner as they viewed five repetitions of each video (600 total videos) while performing a simple task (discriminating mouth from eye videos). First, we replicated our previous result: more anterior regions preferred mouth videos and more posterior regions preferred eye videos. An item-wise analysis that treated stimulus as a random effect revealed substantial inter-stimulus differences within the preferred class, ranging from 0.07% to 0.85% for mouth videos in mouth-preferring STS. To examine the visual features responsible for these differences, we constructed a linear regression model with 5 variables for each stimulus (visual motion energy, contrast, mouth size, mouth motion, mouth typicality). Model fits with and without each feature were compared using the Akaike Information Criterion. Within mouth-selective voxels, the degree of mouth motion within each video was the best predictor of the BOLD response. These findings confirm and extend previous findings of functional specialization related to visual speech processing within the human STS.

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P1.25 Performing a task jointly modulates audiovisual integration in timing and motion judgements

Wahn, B., Dosso, J., Tomaszewski, M. & Kingstone, A. University of British Columbia

Humans constantly receive sensory input from multiple sensory modalities. Via the process of multisensory integration, this input is often combined into a unitary percept. Recent research suggests that audiovisual integration is affected by social factors (i.e., when a task is performed jointly rather than alone) in a crossmodal congruency task (Wahn, Keshava, Sinnett, Kingstone, & König, 2017). However, these findings were concerned with reaction time data and thus it cannot be excluded that social factors affected the preparation or execution of the motor response rather than the audiovisual integration process itself. To address this point, we investigated whether social factors affect perceptual judgements in two tasks (i.e., a motion discrimination task and a temporal order judgement task) that previous research has shown to yield reliable audiovisual integration effects which alter perceptual judgements (Soto-Faraco, Lyons, Gazzaniga, Spence, & Kingstone, 2002; Morein-Zamir, Soto-Faraco, & Kingstone, 2003). In both tasks, pairs of participants received auditory and visual stimuli and each co-actor was required to make perceptual judgements for one of the sensory modalities in a joint and an individual condition. We find that audiovisual integration effects are reduced when participants perform the tasks jointly compared to individually. In an additional experiment, this effect did not occur when participants perform the tasks alone while being "watched" by a camera (i.e., an implied social presence). Overall, our

results suggest that social factors influence audiovisual integration, and that this effect is specific to live partners and not sources of implied social presence.

Acknowledgments: We acknowledge the support of a postdoc fellowship of the German Academic Exchange Service (DAAD) awarded to BW.

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P1.26 Audiovisual integration of spatial stimuli is affected by performing a task jointly

Wahn, B., Keshava, A., Sinnett, S., Kingstone, A. & König, P. University of British Columbia

Humans continuously receive sensory input from several sensory modalities. Via the process of multisensory integration, this input is often integrated into a unitary percept. Researchers have investigated several factors that could affect the process of multisensory integration. However, in this field of research, social factors (i.e., whether a task is performed alone or jointly) have been widely neglected. Using an audiovisual crossmodal congruency task, we investigated whether social factors affect audiovisual integration. Pairs of participants received congruent or incongruent audiovisual stimuli and were required to indicate the elevation of these stimuli. We found that the reaction time cost of responding to incongruent stimuli (relative to congruent stimuli) was reduced significantly when participants performed the task jointly compared to when they performed the task alone. These results extend earlier findings on visuotactile integration by showing that audiovisual integration of spatial stimuli is also affected by social factors.

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P1.27 The Effect of Multisensory Temporal Congruency on Pleasure Yeh, M.S. & Shams, L. University of California, Los Angeles

Pleasure is a commonly shared experience, and yet perceptual pleasure has rarely been studied. Current research has only discussed pleasure in

the realm of aesthetics, and in unisensory modalities. Here, we aim to investigate the relationship between multisensory features and pleasure through the elicited pleasure of paired associated visual and auditory features. This will not only shed light on the experience of pleasure, but also potentially elucidate the relationship between perception and emotion. Our study investigated amodal multisensory association and its effect on felt pleasure. We examined amodal congruency through temporal synchronization between video and soundtrack. Video cuts and emphasized beats in an accompanying soundtrack served as temporal markers, and were synchronized or displaced to create a congruent and incongruent condition. Participants rated each video clip on pleasantness. We found a preference for temporal congruency, suggesting that temporal congruency may be more pleasant. Importantly, this was the case despite the fact that the majority of participants did not notice any difference in temporal congruity across trials. We are also currently investigating the effect of "synaesthetic correspondences" on pleasure in the form of crossmodal associations. Our results indicate that multisensory perceptual features do influence our experience of pleasure, although the specifics remain to be discovered. Future research in this direction has the potential to desirably enhance learning by increasing the associated experienced pleasure.

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P1.28 Role of auditory and visual acuities in temporal binding window measurement

Unnisa Begum, V. & Barnett-Cowan, M. University of Waterloo

The integration of multisensory information allows the central nervous system (CNS) to create a coherent representation of events in the world. Sensory information from more than one modality are perceived as simultaneous when they co-occur within a specific range of temporal offsets called the temporal binding window (TBW)1. The width of the TBW increases with age, leading to difficulty in discriminating temporal order (TOJ)2 and simultaneity (SJ)3 of audiovisual (AV) events. The ability to integrate AV information is dependent on the precise spatial4,5 and temporal discrimination6 of auditory and visual stimuli. With age, visual acuities decline7,8 and hearing impairments are also common with 60% of individuals aged over 65 years exhibiting gradual decline in auditory sensitivities. Studies investigating audiovisual integration do not typically assess unisensory acuity of participants but rather recruit those who selfreport as having normal hearing and vision. As individual and group differences in the perceived timing of multisensory events could largely be explained by differences in sensory acuity, here we propose an economical

and quick approach to measure unisensory auditory and visual acuities using established screening tests. We recruited participants with selfreported normal vision and hearing. Visual acuity was performed using the Freiburg visual acuity test, which is freely available online9. Auditory acuities were determined using a smart phone (Apple, iOS) application 'Ear Trumpet' (PraxisBiosciences, Irvine, California)10. For both SJ and TOJ tasks, participants indicated whether a single auditory beep (1850Hz, 7ms duration) and a flash of light (1cm diameter, 17ms duration) occurred at the same time (SJ task) or if the auditory beep or flash of light occurred first (TOJ task). We will present our preliminary results for how the point of subjective simultaneity and just noticeable difference of the SJ and TOJ tasks are affected by differences in auditory and visual acuity measures.

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P1.29 Robust temporal averaging of time intervals between action and sensation

Chen, L. Peking University

Perception of time interval between one's own action (a finger tap) and the sensory feedback thereof (a visual flash or an auditory pip) is critical for precise and flexible control of action during human-machine interaction and behavioral decision. Previous studies have employed sensorimotor synchronization and sensory-motor temporal recalibration tasks to examine the potential neuro-cognitive mechanism underlying recalibrated representation of timing. In the present study, whether and how temporal averaging (i.e., 'ensemble coding') of the multiple intervals in a train of action-sensory feedback events was investigated. In unimodal task, participants voluntarily tapped their index finger at a constant pace while receiving either only visual feedback (flashs) or only auditory feedback (pip) throughout the train. In crossmodal task, for a given train each tap was accompanied randomly with either visual feedback or auditory feedback. When the sequence was over, observers produced a subsequent tap which elicited a target interval between the tap and its auditory/visual feedback. In both tasks, they were required to make a two alternative choice to indicate whether the target interval is shorter or longer than the mean intervals in the preceding train. In both scenarios, participants' perception of target intervals was assimilated to the mean intervals associated with specific bindings of action and sensation, showing a robust temporal averaging in the loop of action and sensation. Moreover, the precision of temporal averaging was dependent on the variances of the time intervals and individual sensory modality.

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P1.30 Crossmodal associations modulate multisensory integration: modifying causal priors of simple auditory and visual stimuli *Tong, J., Bruns, P., Kanellou, A. & Roeder, B.*

Biological Psychology and Neuropsychology, University of Hamburg

Skilled puppeteers conceal their lip movements while moving a puppet's mouth synchronously with speech sounds to produce the illusion of the voice as originating from the puppet. This "ventriloguism effect" results from the optimal integration of multiple sensory cues. According to the "causal inference" framework, when auditory and visual stimuli have a high prior probability of being causally linked, based on context and past associations, there is strong multisensory integration; on the contrary, when auditory and visual stimuli have a low prior probability of being causally linked, there is weak multisensory integration. Here, we review a behavioral study in which we presented pairs of audio and visual stimuli, during association blocks, as completely congruent or drastically incongruent in both space and time with the goal of driving causal priors in opposite directions. Following these association blocks, each pairwise combination of stimuli was presented in a typical ventriloguism-effect-paradigm with predetermined disparities and stimulus onset asynchronies. Stimuli that had been congruently paired in space and time were subsequently more integrated overall (larger ventriloquism effect) compared to previously unpaired stimuli and compared to stimuli that had been incongruently presented in space and time. A follow-up experiment investigated how auditory stimuli would be localized when presented with two competing visual stimuli on either side, subsequent to association blocks. In agreement with results from the first experiment, auditory stimuli were more shifted toward visual stimuli with which they were congruently paired than for visual stimuli with which they were not congruently paired. Our findings provide support for the causal inference framework, suggesting the existence of causal priors between audio-visual stimuli that can be shaped by experience.

Acknowledgments: Work funded by the German Research Foundation (DFG) award TRR 169, Crossmodal Learning

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P1.31 Different processing of rapid recalibration to audio-visual asynchrony between spatial frequencies *Takeshima*, *Y*.

Doshisha University

The processing of audio-visual integration is affected by the features of visual stimuli. Our previous studies have found that the spatial frequencies of visual stimuli influence this processing. Synchronous perception between visual and auditory stimuli is particularly modulated by spatial frequency. High spatial frequency increases the difference between physical and subjective synchrony. On the other hand, there is the function of recalibration to audio-visual asynchrony. Recent studies have shown that audio-visual recalibration is induced by preceding asynchronous trials in an experiment without explicit periods of adaptation. The present study investigated the effects of spatial frequency on the process of rapid recalibration to audio-visual asynchrony. In this experiment, Gabor patches of two spatial frequencies (i.e., 1 or 5 cycle/degrees) were used as visual stimuli. These Gabor patches were presented with pure tone in various stimulus onset asynchronies, and participants were instructed to respond whether audio-visual synchrony or asynchrony was present. The results indicated that the difference between physical and subjective synchronies was larger in high spatial frequency than in low spatial frequency as seen in our previous study. Moreover, the rapid recalibration effect was also larger in high spatial frequency than in low spatial frequency. Therefore, high spatial frequency induced larger rapid recalibration effect to audio-visual asynchrony. This phenomenon would occur according to the large difference between physical and subjective synchronies, because this large difference is necessary for a large recalibration to asynchrony between vision and audition.

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P1.32 Audio-visual associations show differential effects on auditory and visual responses in the mouse OFC

Sharma, S. & Bandyopadhyay, S. Indian Institute of Technology, Kharagpur

In a dynamic environment where contingencies change rapidly, flexible behaviour is important. The orbitofrontal cortex (OFC) is known for its role in flexible behaviour, decision making and in coding of stimulus value. However, sensory responses in the mouse OFC are poorly understood. We investigate response properties of single neurons in the mouse OFC to multisensory stimuli and that of multisensory associations, specifically, auditory and visual. Retrograde tracer injections in OFC establishes the connectivity between OFC and other areas like PPC, Prh, TeA, potential sources of multisensory information into OFC and also secondary auditory cortex, AuD and secondary visual cortex, V2. Single unit responses to

unisensory, Tone(T)/LED(V), and multisensory stimulus (T+V) were recorded with mean latency to multisensory stimulus in between that of the auditory and visual stimuli. Single neurons in the OFC were found to be primarily (70%) audio-visual in nature. Responses to multisensory stimuli varied from sublinear to supralinear showing nonlinearity in integration of the two stimuli. In order to understand the nonlinear integration underlying the response properties we parse possible types of synaptic inputs (auditory only, visual only and multisensory) onto neurons in the OFC. We used an oddball stimulation paradigm with T/V as standard and V/T as deviant and T+V/T/V as standard and T/V/T+V as deviant. Comparisons were made with trains of T/V/T+V to conclude presence of responses due to the oddball. We conclude the presence of multisensory and unisensory synapses as inputs to OFC neurons. We also see differential effects of association of T and V on auditory responses compared to visual responses, using a T and V pairing paradigm. Based on the above results we propose a hypothetical local circuit model in the OFC that integrates auditory and visual information which may affect computation of stimulus value in a dynamic multisensory environment.

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P1.33 Deficient prepulse inhibition of the startle reflex in schizophrenia using a cross-modal paradigm

Haß, K.H., Bak, N., Szycik, G.R., Glenthoj, B.Y. & Oranje, B. Hanover Medical School

Objectives: To investigate whether the typically reported deficient sensorimotor gating in patients with schizophrenia using unimodal paradigms can also be detected by a cross-modal paradigm which made use of an electrocutaneous-acoustic coupling of stimuli.

Methods: Twenty-four male schizophrenia patients took part in a prepulse inhibition (PPI) paradigm with an electrocutaneous prepulse and an acoustic startle-eliciting pulse. Their results were compared with those from twenty-three healthy males.

Results: As expected, the patients showed significantly lower PPI than controls. No associations were found between measures of illness severity and PPI.

Discussion: To the best of our knowledge, this is the first study showing reduced PPI in patients with schizophrenia by using an electrocutaneousacoustic prepulse-pulse combination. Hence, this study gives further evidence of a modality-independent sensorimotor gating deficit in
schizophrenia. Furthermore, as PPI was also lower than usual in controls using unimodal paradigms, results are interpreted in favour of longer processing times of the electrocutaneous prepulse, which probably led to a shorter perceived stimulus onset asynchrony (SOA) in the brain.

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P1.34 Impaired sensory-motor learning in newly sighted children Pfister, S., Senna, I., Wiebusch, D. & Ernst, M. O. Ulm University

The visual properties of an object, such as its size, influence its perceived weight and are used to predict the required fingertip forces for grasping. If there is a conflict between the visual estimates and actual object characteristics, like in the size-weight-illusion (SWI), the sensory-motor memory is updated such that fingertip forces are quickly scaled to the actual object properties (i.e., the object's real weight), even though the SWI persists perceptually. Hence, the case of distinct processes in vision for action and perception has been made.

What happens if a person only had haptic, but no visual experience of the world so far? To this end, we investigated a sample of Ethiopian children, who previously suffered from dense bilateral cataracts and who were classified as congenitally blind. We compared their grasping performance after cataract removal when they were able to see for the first time, with typically developing children of the same age. Participants lifted three differently sized but equally weighted objects for several times while fingertip forces were recorded.

As expected, controls initially scaled the applied forces to the visually estimated weight of the objects (i.e., greater forces for bigger objects that they expected to be heavier). However, within a few trials these controls scaled the forces to the actual object weight. In contrast, previously blind children did not change their force programming throughout the experiment, hinting to a failure to appropriately use vision for action. This suggests that vision alone without prior visual experience is not enough to make accurate predictions about object weight based on visual size information, despite the fact that they can discriminate the size of the cubes. There seems to be no transfer between previous haptic experience of the world to vision in this kind of grasping task in previously blind children.

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P1.35 Perceptual Training of Multisensory Integration in Children with Autism Spectrum Disorder: A Single-Case Training Study

Dunham, K., Feldman, J.I., Conrad, J.G., Simon, D.M., Tu, A., Broderick, N., Wallace, M.T., & Woynaroski, T. Vanderbilt University

Children with autism spectrum disorder (ASD) demonstrate atypical responses to multisensory stimuli. Specifically, children with ASD exhibit wider temporal binding windows (TBWs) for audiovisual stimuli (see Baum et al., 2015), particularly for complex, social stimuli (e.g., audiovisual speech; Stevenson et al., 2014; Woynaroski et al., 2013). These disruptions in multisensory speech perception may produce cascading effects on language and communication development in children on the autism spectrum. Computer-based perceptual training programs have been shown to narrow TBWs in typically developing adults (De Niear et al., 2018; Powers et al., 2009), and it has been hypothesized that such programs may be similarly effective in children with ASD (e.g., Woynaroski et al., 2013). This pilot study represents an important first step in examining the effects of a perceptual training program on TBWs for audiovisual speech in children with ASD.

A single case (i.e., experimental) research design was utilized over six weeks. Participants were four children with ASD between 7 and 13 years old. The study used a multiple baseline across participants design. Three children participated in baseline and intervention conditions. The introduction and withdrawal of the independent variable (i.e., training) was time-lagged; one control participant who entered treatment with a narrow TBW remained in baseline throughout the study. The dependent variable was TBW derived from a simultaneity judgment task of audiovisual speech syllables. The intervention consisted of the same simultaneity judgment task with automatic, computer-delivered feedback on accuracy following each trial.

Two participants demonstrated a strong effect as a result of intervention. Additionally, the first participant to enter training demonstrated some maintenance of a narrower TBW. Results indicate TBWs in children with ASD may be malleable, but additional research is needed to have high confidence in the causal effects of the training paradigm, and to determine for whom changes in temporal binding are likely to be observed. Limitations due to study design and heterogeneity in subject age and future directions will be discussed.

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P1.36 The Principles of Multisensory Integration in the Rehabilitation of Hemianopia

Dakos, A. S., Jiang, H., Rowland, B. A. & Stein, B. E. Neurobiology and Anatomy, Wake Forest School of Medicine, Winston-Salem, North Carolina

Unilateral lesions of visual cortex induce a profound blindness in the contralateral hemifield (hemianopia). Recent results from our laboratory have demonstrated that this visual defect can be rehabilitated using a noninvasive sensory training procedure involving several weeks of repeated presentations of paired spatiotemporally concordant visual and auditory stimuli. The biological mechanisms supporting this recovery are presumed to involve plasticity mediated by visual-auditory neurons within the midbrain superior colliculus (SC). If so, this rehabilitative success should be constrained by the same spatial and temporal principles that govern the multisensory integration and plasticity of these SC neurons as demonstrated in physiological studies. The present experiments were designed to test this assumption. Animals (n=3) were first trained on a visual localization task. Hemianopia was then induced by large visual cortex lesions. After each animal's defect was observed for 2.5 - 3 months, it was assigned one of two conditions for cross-modal training not designed to produce multisensory enhancement. Two cats received visual-auditory stimuli that were temporally concordant, but spatially disparate. The third received stimuli that were spatially concordant but temporally disparate. The rehabilitation was unsuccessful in each condition even after two months. The training procedure was then repeated for each animal using cues designed to produce multisensory enhancement (e.g., spatiotemporally concordant cues). Rehabilitation was then successful in each group within two months, thereby confirming previous observations. These data are consistent with the hypothesis that the same spatial and temporal principles that govern multisensory integration in individual SC neurons also govern the success of this cross-modal rehabilitative training program. Supported by NIH grants R01EY026916 and F31EY027686 and the Tab Williams Family Foundation.

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P1.37 Sub-clinical levels of autistic traits impair multisensory integration of audiovisual speech

van Laarhoven, T., Stekelenburg, J.J. & Vroomen, J.

Department of Cognitive Neuropsychology, Tilburg University

Autism Spectrum Disorder (ASD) is a pervasive neurodevelopmental disorder characterized by restricted interests, repetitive behavior, deficits in social communication and atypical multisensory perception. ASD symptoms are found to varying degrees in the general population. While impairments in multisensory speech processing are widely reported in clinical ASD populations, the impact of sub-clinical levels of autistic traits on multisensory speech perception is still unclear. The present study examined audiovisual (AV) speech processing in a large non-clinical adult population in relation to autistic traits measured by the Autism Quotient. AV speech processing was assessed using the McGurk illusion, a simultaneity judgment task and a spoken word recognition task in background noise. We found that difficulty with Imagination was associated with lower susceptibility to the McGurk illusion. Furthermore, difficulty with Attention-switching was associated with a wider temporal binding window and reduced gain from lipread speech. These results demonstrate that sub-clinical ASD symptomatology is related to reduced AV speech processing performance, and are consistent with the notion of a spectrum of ASD traits that extends into the general population.

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P1.38 Modified Medial Geniculate Projections to Auditory and Visual Cortex Following Early-Onset Deafness

Trachtenberg, B., Butler, B.E. & Lomber, S.G. University of Western Ontario

Following early-onset deafness, electrophysiological and psychophysical studies have demonstrated crossmodal plasticity, throughout "deaf" auditory cortex. These studies suggest that there may be a functional reorganization of cortical afferents to these reorganized regions of cortex that underlies the crossmodal plasticity. For the most part, retrograde pathway tracer studies of deposits made into auditory cortex have identified little modification in the relative distribution of thalamic and cortical neurons that project to deaf auditory cortex. However, studies of crossmodally reorganized auditory cortex consistently show increased dendritic spine density. These studies suggest that, following early-onset hearing loss, there may also be increased numbers of axon terminals in auditory cortex. To investigate this possibility, we examined efferent projections from the auditory thalamus (medial geniculate body; MGB) of hearing and early-deaf cats in order to reveal the distribution and density of synaptic boutons on thalamocortical neurons. Anterograde fluorescent dextran tracers were deposited bilaterally in the MGB in order to label axon terminals throughout cortex. Axon

terminal labelling in each cortical area was computed as a percentage of all labelled terminals. In hearing cats, the auditory labelling profile of these projections is similar to those of previous tracing studies, with the largest terminal labelling in primary auditory cortex (A1), the posterior auditory field (PAF), and the anterior auditory field (AAF). However, following early-onset deafness, projections from MGB reorganize, and there is increased terminal labelling in visual cortical areas. Therefore, taken together with retrograde studies quantifying auditory thalamocortical projections, it appears that reorganization of projections to auditory cortex is not in the numbers of neurons projecting to a given area, but in the numbers of axon terminals on those neurons.

Acknowledgments: This work is supported by the Canadian Institutes of Health Research.

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P1.39 Perceived Simultaneity and Temporal Order of Audiovisual Events Following Concussion

Wise, A. & Barnett-Cowan, M. University of Waterloo, Department of Kinesiology

The central nervous system allows for a limited time span referred to as the temporal binding window (TBW) in order to rapidly determine whether multisensory events correspond with the same event. Failure to correctly identify whether multisensory events occur simultaneously and their sequential order can lead to inaccurate representations of the physical world, poor decision-making, and dangerous behavior. Damage to the neural systems that coordinate the relative timing of sensory events may explain some of the long-term consequences associated with concussion. The aim of this study was to investigate whether the perception of simultaneity and the discrimination of temporal order of audiovisual stimuli are impaired in those with a history of concussion. 50 participants (17 with concussion history) were recruited to complete audiovisual simultaneity judgment and temporal order judgment tasks. From these tasks, the TBW and point of subjective simultaneity (PSS) were extracted to assess whether the precision and or the accuracy of temporal perception changes with concussion, respectively. Results demonstrated that those with concussion history have a significantly wider TBW (less precise), with no significant change in the PSS (no change in accuracy), particularly for the TOJ task. Importantly, a negative correlation between the time elapsed between the time of concussion diagnosis and the TBW width in the TOJ task suggests that precision in temporal perception does improve over time. These findings suggest that those with concussion history display an impairment in the perceived timing of sensory events and that monitoring performance in

the TOJ task may be a useful additional assessment tool when making decisions about returning to regular work and play following concussion.

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P1.40 Group differences in audiovisual multisensory integration in individuals with and without autism spectrum disorder: A systematic review and meta-analysis

Feldman, J.I., Dunham, K., Samuel, A., Cassidy, M., Liu, Y. & Woynaroski, T.G.

Vanderbilt University

Differences in sensory function are now considered diagnostically significant for persons with autism spectrum disorder (ASD). A number of prior studies have evaluated how individuals with ASD differ from their typically developing peers on measures of multisensory integration (MSI). The present study systematically reviewed and quantitatively synthesized the extant literature on audiovisual MSI in individuals with ASD to (a) better estimate the effect size for group differences between individuals with ASD and TD peers and (b) test a number of theoretically and/or empirically motivated study-level factors that may moderate the overall effect (i.e., explain differential results seen across studies carried out to date).

To identify eligible studies, a comprehensive search strategy was devised using the ProQuest search engine, PubMed database, forwards and backwards citation searches, author contact, and hand-searching of select conference proceedings. Eligibility criteria for studies were (a) confirmation of ASD diagnosis via a standardized measure and (b) inclusion of a behavioral or neural measure of audiovisual integration. Data were extracted from all studies that tested between-group differences (Hedge's g).

A random effects meta-analysis with robust variance estimation procedures was conducted with 108 effect sizes from 48 studies clustered into 32 groups based on overlapping samples between studies. A significant group difference was evident in the literature, g = -0.41, p < 0.001, with individuals with ASD demonstrating diminished audiovisual integration on average compared to TD peers. This effect was moderated by mean participant age, b = 0.03, p = 0.05, such that between-group differences tended to be larger in magnitude in samples of younger versus older chronological ages.

Results indicate that individuals with ASD demonstrate reduced audiovisual MSI compared to their TD peers in the literature, and that these differences are more pronounced earlier versus later in life. Limitations, implications and future directions for primary and meta-analytic research will be discussed.

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P1.41 The Relationship Between Tactilely and Visually Driven Activation of Early Visual Cortex in the Visually Impaired

Stiles, N.R.B., Choupan, J., Jung, E., Purington, C., Wang, J., Law, M., Kashani, A.H., Ameri, H., Aguirre, G K., Weiland, J.D., Patel, V.R. & Shi, Y. University of Southern California

Crossmodal activation of visual cortex by both tactile and auditory stimuli has been shown to occur in the fully blind. However, it has not been extensively studied how the brain transitions from normal visual processing to crossmodal processing in visual cortex as vision is progressively lost with retinal disease.

The Human Connectomes for Low Vision, Blindness, and Sight Restoration research project employs retinal, functional, and fMRI metrics to investigate the interplay of vision and tactile processing in early visual regions of individuals with low vision. In particular, we are interested in individuals with distinct scotomas in the retina that impair vision spatially. We are studying whether tactile activation of visual cortex can occur in the lesion projection zone (the projection of a scotoma onto visual cortex). Namely, does tactile stimulation excite regions of visual cortex that no longer have visual inputs. In addition, we are using functional measures to determine whether or not any partial capture of visual cortex by somatosensation in low vision individuals generates improved performance in tactile tasks.

We will present our preliminary results (N = 11) comparing patients' functional visual and tactile capabilities with the magnitudes and locations of visual cortex activation within the brain during visual and tactile tasks after the onset of low vision. We will also compare early visual cortex activation (extent and amplitude) within the scotoma due a visual flashing light task with visual cortex activation in the same region during two tactile tasks (roughness discrimination and shape symmetry perception). Our preliminary results indicate that the level of residual visual perception plays a critical role in determining the increase in tactile crossmodal activation that is observed to occur in those with low vision.

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P1.42 Alpha oscillations as an index of lip-reading ability

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Audiovisual (AV) integration of spoken language involves the visual modality acting on phonetic representations of the auditory modality. An example of such process is the McGurk illusion, whereby visual context alters the phonetic identity of the acoustic input. In the current study, we sought to understand the relationship between susceptibility to the McGurk illusion and lip-reading ability and the underlying neural mechanisms. EEG was acquired while good and poor McGurk perceivers listened to silent videos of a speaker uttering words and made judgments on whether the words were of animate (e.g., dog, cat), or inanimate (e.g., chair, desk) meaning or unsure about the meaning. We hypothesized that individuals who are susceptible to the McGurk illusion will have stronger lip-reading abilities than those who are poorly susceptible to the McGurk illusion. We further hypothesized that good lip-readers should exhibit greater engagement of visual and auditory areas indexed by desynchronization of alpha-band activity over occipital and central scalp locations, respectively. Our findings showed that the potency of the McGurk illusion did not correlate with lip-reading ability. Furthermore, contrary to our hypothesis, we found that when compared to poor lip-readers, good lip-readers exhibited synchronization of alpha activity over parietal-occipital sites. The alpha results are indicative of reduced engagement of attentional and visual networks and hence reduced cognitive effort in good lip-readers. In short, our findings do not support the premise that lip-reading ability is associated with more robust AV integration, rather they support the hypothesis that good lip-reading ability is associated with reduced attentional demands during visual speech perception.

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P1.43 Audiovisual Integration of Consonant Clusters

Andersen, T.S. &Gil-Carvajal, J-C. Technical University of Denmark

Seeing incongruent visual speech can alter the auditory phonetic percept. In the McGurk fusion illusion the auditory percept is a single consonant different from both the acoustic and the visual consonant. In the McGurk combination illusion the auditory percept contains both consonants. It remains unclear why some audiovisual stimuli elicit combination illusions. It is also unexplored how actual consonant combinations integrate audiovisually. Here we investigate the integration of audiovisually congruent and incongruent combinations of /aba/, /aga/, /ada/, /abga/, and /abda/. We found that visual stimuli containing a bilabial component (/aba/, /abga/ and /abda/) all facilitated perception of both acoustic consonant clusters regardless of audiovisual congruence. This is surprising because incongruent visual stimuli usually lead to illusory, hence incorrect, responses. The effect was most likely caused by the visual bilabial closure as we found a general increase in bilabial responses. Visual consonant clusters also produced combination illusions for auditory /aga/ and /ada/ and these responses were similar to the combination illusion induced by visual /aba/. The velar and alveolar components of visual consonant clusters did, however, also have an effect on auditory perception as they influenced perception of auditory /aba/ in inducing novel combination illusions where subjects perceived /abda/. Acoustic consonant clusters dubbed onto visual velar or alveolar stimuli created novel illusions. For example, acoustic dubbed /abga/ dubbed onto visual /aga/ created an illusion of hearing /agda/ or /adga/. This illusion could be due to the acoustic /b/ and visual /g/ creating a fusion illusion of hearing /d/ while leaving perception of acoustic /g/ unaffected. This indicates that opening, closing and release stages of consonants can integrate differentially. We hypothesise that this may explain why some audiovisual combinations produce combination illusions while others produce fusion or visual dominance illusions.

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P1.44 Vision dominates audition in adults but not children: Adults have a lower threshold for the McGurk effect in audio-visual noise Hirst, R.J., Stacey, J., Cragg, L., Stacey, P.C. & Allen, H.A. University of Nottingham

Across development, humans show an increasing reliance upon vision, such that vision increasingly drives audio-visual perception. This is evidenced in illusions such as the McGurk effect, in which a seen mouth movement changes the perceived sound. The current paper assesses the effects of manipulating the heard and seen signal by adding auditory and visual noise to McGurk stimuli in children aged 3 to 12 years (n=90) and adults aged 20 to 35 years (n=32). Auditory noise increased the likelihood

of vision changing auditory perception. Visual noise reduced the likelihood of vision changing auditory perception. Based upon a proposed developmental shift from auditory to visual dominance we predicted that children would be less susceptible to the McGurk effect, and that adults would show the effect in higher levels of visual noise and with less auditory noise compared with children. We found that susceptibility to the McGurk effect increased with development and was higher in adults than children. Children required more auditory noise than adults to induce McGurk responses and less visual noise to reduce McGurk responses (i.e. adults and older children were more easily influenced by vision). Reduced susceptibility in childhood supports the theory that sensory dominance shifts across development.

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P1.45 Integration of smell and taste: EEG study of brain mechanisms allowing the enhancement of saltiness with aroma

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Odors have the natural property to induce a taste (odor-induced taste enhancement, OITE). Yet odors and taste are perceived through independent senses, which never interact but in the brain. OITE processes are mostly unconscious, but decisive in the pleasure of food. Taste and Smell may interact at different levels of the integration process. The main theory is that the configural pattern of activation is stored in high integration cortices or memory areas and needs to be reactivated in order to induce taste perception, through top-down processes. However, latest findings in rats, showed that early connections between gustatory and olfactory cortices enabled the activation of secondary olfactory cortex (piriform cortex), when rats were stimulated with sugar solution. We wanted here to test these hypotheses in human. We examined the brain chronometry of taste and smell integration with a simple 5 electrodes EEG system, in association with a high time resolution gustometer. We used close to real products, a green-pea soup, two levels of salt "usual" and "reduced" (-25% salt), and an aroma "beef stock". The idea was to compare the soup usually salted (S.usu), and the soup with a reduced level of salt (S.red), with the soup containing a reduced level of salt but a beef stock aroma (S.red.A). The stimulation consisted in 60µl of one solution sprayed as a thin drizzle on the tongue during 400ms (repeated 40 times interleaved by 16 to 20 s water stimulations). As a result, we identified two late pics, N2 and P3, which appeared only in the salty solutions and not in the controls (soup alone and soup with aroma). The differential amplitude N2P3 and for the

S.red.A solution was higher as compared to the S.red. Finally the latency of N2P3 was higher for S.red.A solution as compared to S.usu. As the effects are found in late components of the event related potential, these results seem to confirm the main theory, that aroma may affect taste through the activation of the flavor memory in high integration cortices.

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P1.46 Shapes associated with emotion can influence product taste expectations

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In recent years, there has been a steady interest in unearthing the relation between visual features with both an emotional valence and gustatory tastes. Different studies have demonstrated that visual features such as roundness/angularity, symmetry/asymmetry, and the number of elements can be associated with both an emotional valence and basic tastes (sweet or sour). There is increasing evidence that simple geometric shapes that resemble facial features can be associated with a valence and with an emotion. What is more, there is research showing that experiencing a gustatory taste is generally accompanied by a facial expression. However, there are no studies that have probed as to whether geometric shapes that resemble facial expressions of taste can be matched to basic tastes. This study explores whether shapes that resemble facial expressions influence taste expectations in the context of product packaging. The results indicate that shapes that resemble eyes and mouth-like configurations can be matched to different basic tastes (i.e., sweet, sour, and bitter). We found that the product category has an important influence on the degree in which each of the face-like features influence taste expectations. The present study suggests that low-level visual features may be involved in capturing meaning from facial expressions and opens the possibility that simple facelike features may be used in applied contexts to communicate basic tastes. Our findings hint towards an embodied mechanism for at least some shapetaste associations.

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P1.47 Do Gustatory Global-Local Processing Styles Prime Vision?

Karademas, C. & List, A. Hamilton College

When we perceive sensory information, we can concentrate on either the details or the whole of the object or experience, taking a local or global processing style. We can adopt these processing styles in all five senses. Addressing how adopting a processing style in one modality influenced processing of another modality, J. Förster (2011) reported an extensive series of studies pairing gustatory, olfactory, auditory and tactile senses with vision. Though he reported bi-directional processing style priming between all the pairings he tested, his paper was later retracted based on statistical analyses conducted during an institutionally-driven investigation. Without taking a position on his data, we have instead conducted an independent methodological replication of two of his experiments examining gustatory global-local priming on vision. As in Förster's (2011) reported studies, in one study, we instructed participants to focus on either the details or the whole (goal-driven) or, in a second study, we manipulated the stimuli to promote a local or global focus (stimulus-driven). In both studies, participants first performed a "gustation" task (more accurately described as an eating task because participants derived gustatory, olfactory, haptic and auditory information). We measured whether they subsequently adopted a more global or local processing style during an ambiguous visual matching task. Contrary to Förster's (2011) findings, gustatory global or local focus, whether goal- or stimulus-directed, did not have an effect on visual processing in either study. The current studies not only enhance our understanding of the limits of cross-modal priming, but also contribute more broadly to scientific self-correction through independent research replication.

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P1.48 Psychological effects induced multimodally by the aroma and the color of bottles

Okuda, S. Doshisha Women's College of Liberal Arts

This study aims to clarify how aroma and color of bottles induce multimodally some psychological effects. We prepared six kinds of essences, lavender, lemon grass, cypress, damask rose, spearmint and bergamot as aroma stimuli. Each diluted essence was dropped into a small bottle rapped with one of six kinds of color label, red, orange, yellow, green, blue and purple. We conducted three kinds of subjective experiments. In the visual experiment, participants observed one of the bottles without olfactory

stimulus. In the olfactory experiment, they smelled one of the essences with no visual stimulus. In the visual-olfactory experiment, they observed one of the bottles while smelling one of the essences. Participants evaluated four types of psychological effects, "active", "refreshing", "positive" and "relaxing" effects using numerical scales from 0 to 10. Twenty participants were all female in their twenties, and they were screened using the Ishihara color vision test and the T&T olfactory test. Results of the visual experiment showed that the red and orange bottles caused active and positive impressions whereas the green bottle caused refreshing and relaxing effects. On the other hand, results of the visual-olfactory experiment indicated that the highest active effect was induced when smelling lemon grass in the orange bottle, and that the lowest smelling cypress aroma was induced in the purple bottle. In addition, the induced refreshing effect was the highest when smelling spearmint in the green bottle, and that the induced active effect was the highest when smelling bergamot in the orange bottle. Finally, we found that the average contribution ratios of aroma to color are 1.98 in active effect, 1.78 in refreshing effect, 1.76 in positive effect and 2.32 in relaxing effect, respectively.

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P1.49 Heart rate and skin conductance responses during assimilation and contrast of different juice samples

Verastegui-Tena, L.M., van Trijp, H. & Piqueras-Fiszman, B. Wageningen University and Research

Disconfirmations between consumers' expectations and a product can lead to different processes such as assimilation and contrast . When studied, however, it could be beneficial to have a broader approach into the effects of the disconfirmation of expectations in these processes. For example, food research could benefit from looking at consumers' physiological responses, such as those of the autonomic nervous system (ANS) to understand their initial reactions during these processes. This study evaluated how ANS responses change during assimilation and contrast and whether these responses differ to those obtained when there is no manipulation of expectations.

Eighty-six participants tasted fruit and vegetable juices in two separate sessions. They were divided in two conditions. In the first, expectations were manipulated by showing participants the image of an ingredient and then providing them with juices whose flavours were made congruent, slightly incongruent and largely incongruent to that of the image. In the second condition, the juices were tasted blindly and the image of the ingredient was shown after tasting. Heart rate and skin conductance were measured. To confirm that assimilation, and contrast was experienced, participants rated the samples in different sensory properties before and after tasting each sample. Results showed that most of the sensory ratings, except for that of sourness and taste intensity, showed that there was assimilation and contrast. Heart rate changes were related to whether it was the participants' first or second session doing the study while skin conductance changed according to whether the samples were tasted blindly or not. In conclusion, while our design managed to create situations of assimilation and contrast, ANS responses did not capture factors related to these processes but rather other factors that could be, for example, related to attention and the orientation response.

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P1.50 The homunculus: grounding cognition

Forster, B. & Calvo-Merino, B. City, University of London

Approaches to embodied cognition have shown that language and mental transformations can be grounded in body experiences. These approaches emphasise the link between cognition and the motor system, while we have recently shown the involvement of the somatosensory system in visual tasks involving affective judgments or memory of body images (Sel et al., 2014; GalvezPol et al., 2018). Furthermore, we now show that attentional selection can also recruit additional somatosensory areas in a visual search task. Participants were asked to detect either a certain colour or hand posture amongst several hand images. We analysed visual ERPs evoked by the onset of the visual stimulus display and found the N2pc component over visual cortex reflecting attentional target selection processes. In addition, on half of the trials somatosensory ERPs were elicited by task irrelevant tactile probes presented simultaneous with the visual onset. We isolated somatosensory activity by subtracting visual-only from tactile probe trials. Importantly, only when selecting for posture, but not for colour, the N140cc was present confirming attentional recruitment of somatosensory cortex. Our findings show that embodiment in visual search is not automatic when seeing body images but rather task dependent; and further, our findings extend current assumptions of sensory specificity of attention including the sensory modality perceiving the stimuli and also functionally relevant sensory cortex. Taken together, our findings reveal the distinct role of the homunculus in grounding cognition beyond sensory processes.

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P1.51 More than skin-deep: Integration of skin-based and musculo-skeletal reference frames in localisation of touch

Sadibolova, R., Tamè, L. & Longo, M.R. Birkbeck, University of London

The skin of the forearm is, in one sense, a flat 2D sheet, but in another sense approximately cylindrical, mirroring the volumetric shape of the arm. The role of frames of reference based on the skin as a 2D sheet versus based on the 3D muskulo-skeletal structure of the arm remains unclear. When we rotate the forearm from a pronated to a supinated posture, skin on its surface is displaced. Thus, a marked location will slide with the skin across the underlying flesh, and the touch perceived at this location should follow this displacement if it is localised within a skin-based reference frame. We investigated, however, if the perceived tactile locations were also affected by the rearrangement in underlying musculo-skeletal structure, i.e. displaced medially and laterally on a pronated and supinated forearm, respectively. Participants pointed to perceived touches (Experiment 1), or marked them on a three-dimensional size-matched forearm on a computer screen (Experiment 2). The perceived locations were indeed displaced medially after forearm pronation in both response modalities. This misperception was reduced (Experiment 1), or absent altogether (Experiment 2) in the supinated posture when the actual stimulus grid moved laterally with the displaced skin. The grid was perceptually stretched at medial-lateral axis, and it was displaced distally, which suggest the influence of skin-based factors. Our study extends the tactile localisation literature focused on the skin-based reference frame and on the effects of spatial positions of body parts by implicating the musculo-skeletal reference frame in localisation of touch on the body.

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P1.52 Vision enhances touch just before grasping an object

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Tactile sensitivity measured on the hand is significantly decreased for a moving, as opposed to a resting hand, during the execution of goal-directed movements. This process, known as tactile suppression or gating, is affected by the availability of visual information. However, it is unclear at present whether the availability of visual information during action differentially modulates tactile sensitivity with respect to the different timings of a goal-directed reach-to-grasp movement, especially in what regards the crucial time period shortly before grasping and lifting an object. Here we

investigated this question by having participants reach, grasp, and lift an object placed on the table in front of them, for conditions of full vision, or limited vision (movement executed in the dark), while probing for tactile sensitivity. For this, we utilized measures of signal detection theory (d primes and criterion c'). When present, tactile stimulation was a 2 ms square wave, which was thresholded in a pre-test at rest for a 90% detection level. Tactile stimulation could be delivered with equal probability at the moving or the resting hand, for one of the four different timings of stimulation: movement preparation, movement execution, before grasping, and while lifting the goal object. Our results indicate significant gating of tactile information at the moving, as compared to the resting hand. Importantly, sensitivity at the moving hand is clearly affected by the availability of visual information, for only the before grasp timing of stimulation: That is, tactile sensitivity is clearly enhanced when vision is available, as compared to the blind condition. These results are in line with the well-known visual preference for the index finger in reach-to-grasp tasks and demonstrate, for the first time, that vision also drives what is felt at the index finger when grasping an object.

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P1.53 Pompoms and white blocks should be light: Evidence of how we act upon weight expectations

Wilson, H., Walker, P. & Bremner, G. Lancaster University

Research has shown evidence of a brightness-weight correspondence in which people expect darker objects to be heavier than brighter objects (Walker, Francis, & Walker, 2010). The aim of these experiments was to confirm the presence of this correspondence through verbal measures; and also examine whether the correspondence is revealed through our interactions with objects.

In experiment 1, participants were asked to make weight judgements by vision alone, about identically weighted blocks which varied in terms of material (sand, pompom), which was thought to be a relatively obvious cue to weight, or brightness (grey, black, white). As expected, in the material trials, participants rated the pompom block as the least heavy and the sand block as the heaviest. In the brightness trials, the brighter block was rated as lighter in weight than the darker block. Using verbal measures, this confirmed the presence of a material-weight and brightness-weight correspondence.

Research has shown that people reach and transport objects differently based on their expected weight (Eastough & Edwards, 2007; Paulun, Gegenfurtner, Goodale, & Fleming, 2016). In experiment 2, participants were asked to lift a series of blocks (same stimuli as experiment 1), to examine whether there were differentiated kinematics for objects of different brightness. Material blocks were also included to see how kinematics vary for arguably a more obvious correspondence. Sand blocks were lifted significantly higher during transport than pompom blocks (p = .011), suggesting that more force was used to lift the 'heavier' block. Black blocks were approached with significantly greater maximum velocity than white blocks (p = .032). It is suggested this is evidence that more caution was taken with the 'lighter' block. This demonstrates early evidence that the brightness-weight, crossmodal correspondence is utilised in everyday interactions with objects.

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P1.54 Audiovisual Interactions in Primary Auditory Cortex of the Mongolian Gerbil (Meriones unguiculatus) Probed with Amplitude-Modulated Stimuli

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The anatomical substrate of cortical and subcortical audiovisual connections in the Mongolian gerbil are well described. However, the functional characterization of audiovisual interactions in this species is largely missing.

To ameliorate this knowledge gap we recorded with silicone probes in primary auditory cortex of Ketamine/Xylazine anesthetized gerbils. We presented stimuli via two free-field speakers and speaker-mounted light-emitting diodes (LEDs) located at 60 deg contralateral/ipsilateral re. recording side (distance re. head: 107 cm). Auditory (noise) and visual (light) stimuli consisted of a 500-ms static part followed by a 500-ms amplitude-modulated part. The leading static part was present in all stimuli. In unimodal auditory (visual) stimuli only the noise (LED) was amplitude modulated while the LED (noise) remained static. In audiovisual stimuli both sound and LED were amplitude modulated. We systematically varied a) modulation frequency, b) modulation depth, c) the delay between modulation onset of sound and LED, d) LED color (red, green, blue), and e) LED location (contra/ipsi).

In congruence with the literature we found modulatory effects of visual stimulation in auditory cortex. We observed both facilitatory and

suppressive interactions with congruent and incongruent modulation frequencies. The strongest audiovisual interactions occurred with small temporal delays (+/-100 ms). Audiovisual responses to amplitude modulation could lead or lag re. unimodal responses. Surprisingly, depending on the delay between sound and LED additional response peaks could arise which were absent in unimodal conditions. Furthermore, we found a positive correlation between audiovisual interactions and LED modulation depth. And, audiovisual interactions were diminished or absent with red-light or ipsilateral LED stimulation. All of these effects occurred in both hemispheres.

We conclude that a) the main principles of multisensory integration hold true for gerbil auditory cortex, b) amplitude-modulated sounds and lights are suitable stimuli for the study of audiovisual integration and may be useful surrogates for complex audiovisual speech stimuli.

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P1.55 Endogenous attention enhances neuronal signature of audio-visual sound-shape correspondence

Chow, H.M. & Ciaramitaro, V.C. University of Massachusetts Boston

Associations between abstract shapes and non-sense words, e.g., round shapes and /bouba/ sounds, have been observed across cultures and early in development. Yet, how automatic is this association and does attention influence such crossmodal correspondence? More specifically, does attending a sound enhance representation of the corresponding (congruent) shape feature naturally associated with this sound? We investigated the role of attention in sound-shape correspondence using steady state visual evoked potentials (SSVEPs) recorded by electroencephalography.

Participants viewed one spikey and one round shape, half a shape in each visual hemifield. Each shape flickered at one of two frequencies (5.45, 7.5Hz) under one of three auditory conditions: no sound, or a /ba/ or /ki/ sound repeated at 3Hz. Across blocks, endogenous attention was directed away from shapes and sounds (participants detected color changes at

central fixation) or distributed uniformly across shapes and sounds as which stimulus would change was unpredictable (participants detected border thickness changes in shapes and volume reduction in sounds). We expected a feature-based attentional enhancement: enhanced neuronal processing of a visual shape (e.g., round shape) by a concurrently presented congruent sound (i.e. /ba/) and/or reduced processing by an incongruent sound (i.e. /ki/). We quantified neuronal processing by measuring the signal-to-noise ratio of the SSVEP at the fundamental frequencies (5.45 and 7.5Hz) of each visual shape.

Our results suggest an enhanced occipital SSVEP signal-to-noise ratio for a given shape by a congruent over incongruent sound, such that attending a sound enhances the corresponding visual shape in accord with sound-shape correspondences. Interestingly, such effects emerge when attention is directed towards sound and shape features but not when attention is directed away. Our results highlight that neuronal signatures of audio-visual sound-shape correspondence are influenced by endogenous feature-based attention, which may act globally across corresponding visual and auditory features.

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P1.56 Multisensory Responses in the Primary Auditory Cortex of the Cat Boucher, C., Butler, B. & Lomber, S. G. University of Western Ontario

Core auditory cortex of the cat is comprised of primary auditory cortex (A1) and the anterior auditory field (AAF). Neurons in both fields respond strongly to acoustic stimuli and are tonotopically organized. In hearing animals, a small number of cells in AAF respond to tactile stimulation. Following early-onset hearing loss, a much larger proportion of neurons in AAF become responsive to tactile and/or visual stimulation, indicating that the crossmodal sensory reorganization is robust in this cortical area. Unfortunately, the results from similar studies of A1 neurons are not as clear. In hearing cats, studies do not show multisensory responses in A1 (Stewart & Starr, 1970; Rebillard et al., 1977; Kral et al., 2003). Furthermore, only one study has documented crossmodal plasticity in A1 following perinatal hearing loss (Rebillard et al., 1977), while others have not (Stewart & Starr, 1970; Kral et al., 2003). An important methodological consideration surrounding these studies involves whether the anesthetic used may have played a role in revealing crossmodal plasticity in deaf A1. Overall, studies that used ketamine or pentobarbital as the primary anesthetic were able to identify crossmodal plasticity in deaf A1, while studies utilizing halothane were not. Therefore, the purpose of this

investigation was to examine whether crossmodal responses might be evident under ketamine. Here, we measure multisensory responses in A1 of hearing animals and examine the visual characteristics to which A1 maximally responds. These results will serve as a control for future studies that will examine the degree to which A1 undergoes crossmodal plasticity following perinatal deafness.

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P1.57 Hand distance modulates the electrophysiological correlates of target selection during a tactile search task

Ambron, E.A., Mas-Casadesús, A.M.C. & Gherri, E.G. University of Pennsylvania

This study investigated whether the N140cc ERP component, described as a possible electrophysiological marker of target selection in touch, was modulated by body posture. Participants performed a tactile search task in which they had to localise a tactile target, presented to the left or right hand, while a simultaneous distractor was delivered to the opposite hand. Importantly, the distance between target and distractor (hands separation) was manipulated in different experimental conditions (near vs. far hands). Results showed reduced errors and enhanced amplitudes of the late N140cc when the hands were far apart than in close proximity. This suggests that the competition between target and distractor is stronger when the hands are close together in the near condition, resulting in a degraded selection process. These findings confirm that the N140cc reflects target selection during the simultaneous presentation of competing stimuli and demonstrate for the first time that the attentional mechanisms indexed by this ERP component are based at least in part on postural representations of the body.

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P1.58 Networks supporting auditory-visual speech: evidence from invasive neural recordings in humans

Ahn E., Plass J., Rakochi A., Stacey W. & Brang D. University of Michigan

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/) can alter the

perceived content of speech. 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 fMRI indicates that phoneme information extracted from lip movements facilitates the processing of auditory speech signals through a network involving the posterior superior temporal sulcus. While fMRI is adept at examining large changes in local activity, it is relatively insensitive to other forms of neural communication, particularly those used in multisensory contexts such as phase-resetting of intrinsic oscillatory activity. Furthermore, fMRI lacks the temporal resolution needed to identify some time-varying aspects of network communication. To better understand the neural mechanisms through which lip articulations modulate auditory speech perception, we acquired intracranial electrocorticographic recordings from a large group of patients (n=15) during an auditory-visual speech perception task. Examining event-related potentials, low-frequency oscillatory activity, and measures of population spiking rates, we show that lip articulations relay information across a network involving posterior fusiform face areas and visual motion area MT to temporal auditory areas, modulating auditory processes before the onset of speech signals. 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.

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P1.59 Event-related brain potentials (ERPs) during peripheral and central visual field stimulation in the context of self-motion perception (vection)

Keshavarz, B., Haycock, B., Adler, J. & Berti, S. Toronto Rehabilitation Institute - University Health Network

The perception of self-motion can be induced by the sole stimulation of the visual sense in the absence of actual, physical movement (vection). The present study measured human event-related brain potentials (ERPs) to investigate the sensory processes underlying vection. We presented participants a visual stimulus consisting of alternating black-and-white vertical bars that moved in horizontal direction for a brief period (2.5s-3.5s). When presented for a longer duration, the stimulus created the sensation of circular vection about the yaw axis. The stimulus was presented on a screen that was divided into a central and a surrounding peripheral visual area. Both areas moved independently from each other, requiring an intravisual integration of the peripheral and central stimulation. This resulted in four different movement patterns: (1) the peripheral and the central stimulus moved in the same direction, (2) in opposite directions, (3) the peripheral

stimulus remained stationary while the central field moved, or (4) vice versa. The visual stimulus was varied with respect to the bars' width (narrow vs. wide). Vection intensity and duration were verbally collected. In general, the visual stimulation elicited vection that varied with respect to intensity and duration (i.e., weakest and shortest vection with central stimulus moving and peripheral stimulus stationary). ERP results demonstrated that movement onset of the stimulation elicited parieto-occipital P2 and N2 components. The amplitudes of the ERP components differed significantly between the four movement patterns (irrespective of stimulus type), however, they did not fully represent the subjective vection ratings reported by the participants. We argue that the ERP findings reflect the early sensory processing stage that precedes and contributes to the subjective sensation of vection.

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P1.60 Disentangling processing speed-up versus true multisensory integration using Support Vector Machine method Mercier M.R. & Cappe, C. CNRS

It is now recognized that multisensory integration starts early in the sequence of sensory processing. As a consequence, it introduces temporal difference in the dynamic of brain activation, making difficult the assessment of later multisensory integration effect(s). That is to evaluate if any later difference between multisensory and unisensory conditions is truly related to multisensory integration or simply a corollary of the early multisensory integration effect. To resolve this confound we propose here a new type of analysis based on Support Vector Machine.

Support Vector Machine method provides extremely powerful tools for analyzing complex and dense dataset. In neuroscience this approach has been largely employed in brain imaging, where it is often referred as Mutli-Variate Pattern Analysis. Recently several EEG and MEG studies have illustrated its relevance to decode brain activity in time, for instance to discriminate brain activations related to visual categories.

In the present research we present a new approach to portray multisensory integration processes. Based on the additive model, we use a linear classifier first trained on the sum of unisensory conditions and then tested on the multisensory condition. The output of the classifier reflects its performance to determine the amount of brain signal elicited in the multisensory condition which can be predicted by the additive model. Moreover a temporal generalization technique allows us to disentangle true multisensory effect from speeded/lagged effect when comparing multisensory condition to unisensory conditions.

We illustrate this new approach in an EEG experiment in which subjects had to identify unpredictable auditory and/or visual targets embedded within a stream of audiovisual noise. The results reveal two types of "multisensory effect". One related to integration processes and another one accounting for the speed-up of cognitive processes. We further extend the relevance of this new approach in extracting signal related to decision process.

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P1.61 Visual Activation and Lateralized Area Prostriata Induced During a Perceived Trance Process by an Expert

DeSouza, J.F.X. & Rogerson, R. York University

Altered states of consciousness have been recorded worldwide since time immemorial. Although viewed until recently as cultural phenomenon, which defies diagnostic criteria (Huskinson 2010), neuroscientists are increasingly investigating changes in brain circuitry during trance processes. The authors used an fMRI to explore perception of a trance process through a case study with an experienced Isangoma (traditional South African healer) with the aim of exploring the BOLD signal in associated regions. Following a stimulus of music selected by the healer to induce trance, a 3T Siemens Tim Trio MRI scanner was used to acquire functional and anatomical images using a 32 channel head coil. The data using the General Linear model (GLM), based on her perceptions of when she reported experiencing trance showed positive BOLD activation in visual, auditory cortex in both hemispheres. Other brain regions that showed a tight correlation to her trance perception was the right parietal, right frontal and right area prostriata at (P<0.05, Bonf). The orbitofrontal cortex was most negatively correlated to the perception of trance and showed the largest difference of high compared to low trance perception. It is the culturally appropriate auditory stimulus which seems to trigger a trance process in the subject. In Hove's et al (2015) comparative research of shamans in perceived trance, brain regions as anatomical seeds is evident. While in the author's findings, a higher correlation of perceived trance in the subject in all areas (dACC, posterior ACC and their PPC regions) is visible. Unlike Hove et al however, the author's show a strong correlation to the subject's perceived trance and hope not only to exemplify correlations of trance perception but also to add to budding neuroscientific inquiry regarding brain circuitry and trance processes.

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P1.62 Parkinson's Disease and Oscillatory Brain Rhythms: Putative EEG changes in Parkinson's patients performing the sound induced double-flash illusion task before and after neurorehabilitation.

Cohan, R. & DeSouza, J.F.X. Department of Psychology, Centre for vision research, York University

A mounting body of evidence suggests that the prodromal and clinical symptoms of Parkinson's disease (PD) such as impaired circadian rhythm, uncoordinated movements, and distortion in beat and time perceptions could be explained by the decrease in the dopamine-dependent oscillatory brain rhythms. Multiple studies have confirmed the role of decreased levels of global alpha frequency (8-14 Hz) as one of the main underlying neurophysiological causes of sub-optimal perception and movement in PD.

In the past few years novel neurorehabilitation interventions such as dance have shown a marked improvement in the post-intervention alpha power, emphasizing the importance of external multisensory cues for patients with PD (PwPD). In the case of dancing, the amalgamation of movement to the music, copying the instructor, and synchronizing movements with the partner, could all be the plausible mechanisms for the post therapy improvements.

There seems to be a correlation between dance, alpha frequencies and amelioration of symptoms, therefore, we hypothesized that PwPD should show an improved length of temporal window of perception postintervention coupled with an increased alpha frequencies. Our team uses the sound-induced double flash illusion paradigm to test the temporal window of sensory integration during the coupling of sound and visual stimuli in two groups of PD and healthy age-matched controls before and after dance. A third group was also added to control for possible dopaminereplacement therapy (mainly L-dopa and Carbidopa) interference with alpha frequencies.

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P1.63 Short- and long-term evaluation of the effects of dance on people with Parkinson's Disease.

Bearss, K. & DeSouza, J.F.X York University

Dance is a multi-dimensional physical exercise, involving widespread activity of different brain regions as well as demonstrates positive short-term benefits on motor function for people with Parkinson's Disease (PwPD). Our current study examines the effects of dance training on both motor and non-motor symptoms, and correlates these effects to onsite recordings of rsEEG. METHODS. Short-term: 17 PwPD, mild-severity (MH&Y= 1.31, SD= 1.01) (Mage = 68.82, SD = 8.95, NMales = 12) and 19 healthy controls (HC) (Mage = 52.78, SD = 17.30, NMales = 6); and Long-term: 16 PwPD, mildseverity (MH&Y= 1.25, SD= 0.86), (Mage= 68.73, SD= 8.41, NMales= 11, MDiseaseDuration= 5.54, SD= 4.52) were tested before and after dance class using the standardized MDS-UPDRS (I-IV), H&Y, PANAS-X, MMSE, PD-NMS and rsEEG over 3 years. RESULTS. Short-term: PwPD showed greater motor impairment in comparison to HC (p < .001, $n^2 = .714$). Motor impairment improved after a dance class (p < .001, n2 = .479). A significant interaction was found between Condition (PRE vs POST) and Group (PD vs. HC), with motor improvement in PwPD following the dance class (p < p.01, n2 = .479). Negative affect decreased after dance class for both PD and HC (p < .01, $\eta 2 = .503$). Positive affect was higher after dance class (p < .01, $\eta 2 = .255$). An interaction in positive affect scores between Condition and Group, where HC positive affect increased after the dance class (p < .025, $n_2 = .179$). rsEEG global alpha power was highest after the dance class (p < .025, n2 = .210). Long-term: There is no motor impairment progression of PD across 3-years (p = .685). CONCLUSIONS. Results indicate the positive benefits of dance for motor, non-motor and neural changes in PwPD. These findings support the implementation of dance as a form of neurorehabilitation for PwPD.

Acknowledgments: We thank our current and past students and volunteers for their ongoing hard work and dedication to the JoeLab and the Dancing with Parkinson's project.

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P1.64 A vestibular-gravitational contribution to perceived body weight Ferrè, E.R., Frett, T., Haggard, P. & Longo, M.R. Royal Holloway University of London

The weightlessness experienced by astronauts has fascinated scientists and the public. On Earth, body weight is given by Newton's laws as mass times gravitational acceleration. That is, an object's weight is determined by the pull of gravity on it. We hypothesised that perceived body weight is – like actual weight – dependent on vestibular-gravitational signals. If so, changes in the experienced force of gravity should alter the experience of one's own body weight. We asked participants to estimate the weight of two body parts, their hand or their head, both in normal terrestrial gravity and during exposure to experimentally altered gravitational fields, 0g and +1.8g during parabolic flight and +1g using a short arm human centrifuge. For both body parts, there was a clear increase in perceived weight during experience of hypergravity, and a decrease during experience of microgravity. Our results show that experimental alterations of gravity produce rapid changes in the perceived weight of specific individual body parts. Traditionally, research has focused on the social factors for weight perception, as in the putative role of mass media in eating disorders. In contrast, we emphasize that the perception of body weight is highly malleable, and shaped by immediate sensory signals.

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P1.65 Perceived timing of active head movements reduced with increased speed

Sachgau, C., Chung, W. & Barnett-Cowan, M. University of Waterloo

The central nervous system must determine which sensory events occur at the same time. Actively moving the head corresponds with large changes in the relationship between the observer and the environment, sensorimotor processing, and spatiotemporal perception. Numerous studies have shown that head movement onset must precede the onset of other sensory events in order to be perceived as simultaneous, indicating that head movement perception is slow. Active head movement perception has been shown to be slower than passive head movement perception and dependent on head movement velocity, where participants who move their head faster than other participants require the head to move even earlier than comparison stimuli to be perceived as simultaneous. These results suggest that head movement perception is slower (i.e., suppressed) when the head moves faster. The present study used a within-subjects design to measure the point of subjective simultaneity (PSS) between active head movement speeds and a comparison sound stimulus. Our results clearly show that i) head movement perception is faster when the head moves faster withinsubjects, ii) active head movement onset must still precede the onset of other sensory events (Average PSS: -123 to -52 ms) in order to be perceived as occurring simultaneously even at the fastest speeds (Average peak velocity: 76°/s to 257°/s). We conclude that head movement perception is slow, but that this delay is minimized with increased speed.

While we do not provide evidence against sensory suppression, which requires active versus passive head movement comparison, our results do rule out velocity-based suppression.

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P1.66 Is linear vection enhanced when perceived upright is orthogonal to gravitational upright?

McManus, M. & Harris, L.R. Centre For Vision Research, York University

When gravity cues are unavailable or become unreliable, visual information is weighted more strongly (Harris et al, 2017 Microgravity 3:3). If a conflict is introduced between the body, gravity, and visual cues to upright the reliability of non-visual cues may decrease and thus, since cues are weighted according to their reliability, enhance vision. Here we tested this hypothesis using the perceived travel distance induced by optic flow in the presence or absence of a conflict between visual and non-visual orientation cues.

Participants were tested standing, supine, or prone (thus varying the relationship between gravity and visual orientation cues) in either a structured visual environment aligned with their body or a star-field. During each trial a target was simulated in an Oculus Rift at between10 and 80m in front of them. The target was then removed, and participants were virtually accelerated towards the target's previously seen location. They pressed a button when they reached the remembered target location. Experiments used a random block design. Following each block, participants' perceived upright was assessed.

Pilot studies using the structured-vision condition found that in the supine and prone postures, participants experienced a visual reorientation illusion (VRI) such that they felt that they were upright and aligned with gravity even though they were physically orthogonal to gravity, indicating a dominance of vision. In this condition, participants in supine and prone postures needed to travel less far than in the upright condition to perceive they had traveled through the target distance.

We conclude that conditions of sensory conflict can increase reliance on vision. The star field condition will allow us to determine if this due to reweighting of sensory cues associated with a VRI.

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Canadian Space Agency. MM holds a research studentship from the NSERC CREATE program.

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P1.67 When in conflict, choose touch! A visuo-haptic, virtual reality investigation of conflicting shape information in object processing *Kang, H.M.*

Korea University, Brain and Cognitive engineering, Cognitive systems Lab

"Several studies have investigated how vision and touch are integrated and whether one modality may be dominant. A study by Rock and Victor famously claimed that when visual and touch information are incongruent, the brain chooses the visual input, which they called "visual capture". Here, we extend this research on multisensory integration by separating vision and touch in a virtual reality (VR) setup using parametrically-generated, novel 3D shapes. Observers see a shape in VR and touch a shape in the real world with the help of 3D-printed objects. The exploration is displayed in real-time via hand tracking in VR to increase immersion and believability.

We use a simple shape similarity judgment task with multiple, interleaved staircases to investigate shape perception using congruent (visual and haptic shapes are the same) and incongruent conditions (two modalities differ). Two objects are presented subsequently and participants have to indicate whether they are same or different. Since the objects are parametrically-generated, we can vary both the difference between the first and the second object, as well as the difference between the visual and the haptic display. The staircases are used to find the parameter difference that results in a "same" response.

18 participants were recruited in each of three groups to test the influence of instruction on the similarity judgment: 'no instruction', 'attend vision' and 'attend touch'. We found that congruent and incongruent conditions were significantly different in all three groups (all p<.001) – importantly the result showed that participants were biased towards haptic shape judgments, contradicting the earlier findings by Rock and Victor. Although there was a trend towards group differences, our results showed no significant difference in the amount of "haptic capture" with respect to instruction (F=2.345, p=.101).

Overall, our findings show a surprisingly resistant haptic dominance in judging conflicting information on shape."

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P1.68 Vestibular signals modulate perceptual alternations in binocular rivalry from motion conflict

Keys, R.T., Paffen, C., MacDougall, H., Alais, D. & Verstraten, F.A.J. School of Psychology, University of Sydney

Visual and vestibular information are both informative about self-motion and recent work shows that vestibular signals can influence visual motion perception. Here we ask whether vestibular input can influence the dynamics of binocular rivalry created by opposed visual motions. In 64 s trials, 10 observers in a CKAS 6 degrees-of-freedom motion platform system (Hexapod) underwent sinusoidal yaw rotations that oscillated between ±15 degrees with a full cycle period of 4 seconds while viewing motion rivalry. Observers viewed left- and rightward moving gratings which were dichoptically presented via an Oculus head-mounted display, and continuously tracked their dominant visual motion percept while their head and eye movements were recorded. The rivalry tracking time-series were epoched into 4 s periods to line up with one cycle of self- motion and averaged to show the mean dominance percept for every position of the yaw-rotation cycle. Fitting a sinewave to the epoched data of each participant showed that rivalry dominance tended to correlate with the direction of yaw rotation. The group mean sine period was 3.88 s, indicating that the motion rivalry dynamics were entrained by the self-motion oscillation. Fitted sine amplitudes varied between observers from 0.04 to 0.31, relative to a maximum amplitude of 0.5. The phase of the sine fitted to the rivalry alternations was stable and tightly linked to the phase of yaw rotation. For 7/10 observers it was in-phase (the dominant motion matched the direction of self-motion), and for 3/10 it was in anti-phase (the dominant motion was opposite to the direction of self-motion). Control data showed that the same yaw rotation had no influence on motion rivalry dynamics between upwards and downwards directions. We conclude that vestibular signals from self-motion input to the visual system and can help resolve perceptual ambiguity from motion rivalry.

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P1.69 Illusions of self-motion perception in the visual and vestibular systems during cue conflict

Kirollos, R. & Herdman, C. M. Carleton University - Center for Visualization and Simulation

In most situations, the information received by the visual, vestibular and other sensory systems regarding our self-motion is consistent. However,

there are circumstances in which the sensory systems receive conflicting self-motion information, causing disorientation and potentially motion sickness. Most research supports the notion that the visual system overrides other cues for deciding self-motion direction during sensory conflict. However, much of the research on self-motion has not isolated the unique contribution of the vestibular system. The present research examined whether the visual or the vestibular system dominates during cue conflict in deciding self-motion direction. Measures of perceived illusory speed, direction and duration were indexed using a device that participants rotated when they experienced self-motion. In Experiment 1, caloric stimulation was used to deliver cool air to the inner ear. This changed the fluid dynamic properties of the horizontal semi-circular canal, resulting in illusory self-rotation in the yaw axis. In Experiment 2, visual illusory selfrotation was induced in the yaw axis using a stimulus presented on a virtual reality headset. In a final experiment, participants received visual and vestibular cues to self-rotation simultaneously that signalled motion in opposite directions but that were of approximately equal perceived speed. Surprisingly, results indicated that participants relied on the direction of motion signalled by the vestibular cues during cue conflict as often as they relied upon visual cues. These results suggest that the vestibular system has an equally important role in deciding self-motion direction during cue conflict and that self-motion direction is not dominated by visual cues during cue conflict. Future research should focus on the use and development of more precise methods to stimulate the vestibular system to further uncover its contribution to self-motion perception.

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P1.70 Feeling the beat: An exploration into the neural correlates of somatosensory beat perception

Gilmore, S. & Russo, F. Ryerson University

Musical rhythms elicit a perception of a beat (or pulse) which in turn tends to elicit spontaneous motor synchronization (Repp & Su, 2013). Electroencephalography (EEG) measurement has revealed that endogenous neural oscillations dynamically entrain to beat frequencies of musical rhythms even in the absence of overt motor activity, providing a neurological marker for beat perception (Nozaradan, Peretz, Missal, & Mouraux, 2011). Although beat perception seems to show an auditory advantage, recent research suggests that rhythms presented through tactile stimulation of the skin can also elicit motor synchronization, albeit to isochronous rhythms only (Ammirante, Patel, & Russo, 2016). The current research passively exposes participants to simple and complex rhythms from auditory, tactile, and audio-tactile sources. In addition, following passive exposure all participants will complete an active sensorimotor synchronization task with the same stimuli. Fourier analysis of EEG recordings and timing precision of sensorimotor synchronizations will be compared across the different modality conditions. Data collection for this study is currently in progress. Results may provide evidence that informs best-practices regarding tactile perception of rhythm, as well as provide a broader understanding of the auditory advantage for beat perception. Finally, the results may lead to new insights regarding the potential for multimodal enhancement of beat perception.

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P1.71 The Development of Auditory-tactile Integration

Stanley, B., Chen, Y.C., Lewis, T.L., Maurer, D., & Shore, D.I. McMaster University

Adults form a single coherent percept of the environment by optimally integrating sensory signals from multiple modalities. However, this ability changes throughout childhood and into adolescence. Here we measured the developmental changes using the fission and fusion illusions. Fission occurs when a single stimulus (e.g., tap to the finger) is perceived as two when accompanied by two stimuli from another modality (e.g., auditory beeps); fusion occurs when two stimuli are perceived as one when accompanied by a single stimulus from another modality. Three groups of children (9-, 11-, and 13-year-olds) and adults were tested on both the tap illusion induced by sound and the sound illusion induced by tap. Participants reported how many taps (or sounds) they perceived while instructed to ignore the signals in the other modality. On each trial, either one or two taps (beeps) was accompanied by either 0, 1, or 2 beeps (taps). Congruent trials consisted of equal numbers of taps and beeps; incongruent trials consisted of combinations of stimuli to produce fission or fusion illusions. The magnitude of the illusions was calculated by subtracting the accuracy on incongruent trials from that on congruent trials. The results to date (N = 18-20/group) reveal three findings of interest. First, the magnitude of the fission illusion exceeded the magnitude of the fusion illusion in all age groups. Second, the tap illusion induced by sound was greater than the sound illusion induced by tap for all age groups tested. Third, the magnitude of fission for the tap illusion induced by sound tended to be larger in 9-year-olds, but similar in 11-year-olds as compared to adults. In contrast, there was no age-related difference observed for fission in the sound illusion induced by tap. Finally, the pattern of results was not completely 概泠□揭敫甠瑮汩幺%觳牡□景愠敧∮ćDance, an inten

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P1.72 Decoding the sound of hand-object interactions in early somatosensory cortex

Bailey, K. M., Giordano, B. L., Kaas, A. & Smith, F. W. University of East Anglia

Neurons, even in earliest sensory regions of cortex, are subject to a great deal of contextual influences from both within and across modality connections. Such connections provide one way for prior experience and the current context to shape the responses of early sensory areas. Recently we have shown that cross-modal connections from vision to primary somatosensory cortex (S1) transmit content-specific information about familiar but not unfamiliar visual object categories. In the present work, we investigated whether hearing sounds depicting familiar hand-object interactions would also trigger such activity in S1. In a rapid event-related fMRI experiment, right handed participants (N=10) listened to five exemplars from each of three categories of auditory stimuli: hand-object interactions (e.g. bouncing a ball), animal calls (e.g. dog barking), and pure tones (unfamiliar control). Participants listened attentively, and performed a one-back repetition counting task, which eliminated any need for a motor response during scanning. An independent finger-mapping localizer was completed afterwards, and used to define finger-sensitive voxels within anatomically drawn masks of the right and left post-central gyrus (rPCG and IPCG respectively). Multivariate pattern analysis revealed significant decoding of different hand-object interactions within bilateral PCG. Crucially, decoding accuracies were significantly higher for decoding handobject interactions compared to both control categories in rPCG. In addition, decoding of pure tones was at chance in all analyses. These findings indicate that hearing sounds depicting familiar hand-object interactions elicit different patterns of activity within finger-sensitive voxels in S1, despite the complete absence of tactile stimulation. Thus cross-modal connections from audition to early somatosensory cortex transmit content specific information about familiar hand-action sounds. Our results are broadly consistent with Predictive Coding views of brain computation, which suggest that the key goal of even the earliest sensory areas is to use the current context to predict forthcoming stimulation.

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P1.73 Musical expertise weakens the cost of dividing attention between vision and audition

Ciaramitaro, V.M., Chow, H.M., & Silva, N. University of Massachusetts Boston

Recently we found that dividing attention across sensory modalities in a bimodal dual-task can impair performance, decreasing auditory contrast sensitivity, under high versus low visual load (Ciaramitaro et al., 2017). Musical training involves concurrently attending two or more senses (e.g. reading musical scores and listening to sounds) and can weaken the cost of unimodal dual-task performance (Moradzadeh et al., 2015). Here we investigate if musical experience weakens the cost of bimodal dual-task performance.

Participants performed an audio-visual dual task containing two intervals of binaural white noise and a concurrent RSVP stream of letters at fixation. For the auditory task, participants reported which interval contained an amplitude modulated white noise, with modulation depth varying across trials. For the visual task, participants judged which interval contained white letters (easy visual task) or a greater number of the target letter 'A' (difficult visual task). We measured auditory contrast sensitivity by fitting auditory data with a Weibull function to determine auditory thresholds. To quantify the cost of crossmodal attention we compared visual accuracy and auditory thresholds across easy and hard visual conditions. We expected a smaller cost on auditory performance from a competing harder versus easier visual task in musicians (n=28) compared to non-musicians (n=16). Individuals were classified as musicians if they met 2 (amateur; n=16) or 3 (experienced; n=12) criteria: at least 10 years musical training, training onset by 8 years of age, or younger, 15 hours practice per week, on average.

We found a smaller cost of divided crossmodal attention for musicians versus non-musicians. However, only male, not female, musicians showed enhanced auditory processing, smaller auditory contrast sensitivity differences for high versus low visual load, with concurrent weaker or no differences in visual performance. Some gender differences may reflect musical competence differences of our select sample not specified in our criteria.

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P1.74 Spatial attention modulates multisensory selection Jensen, A., Merz, S., Spence, C., & Frings, C. University Trier

In daily life, signals from different sensory modalities are integrated in order to en-hance multisensory perception. However, an important, yet currently still controversial, topic concerns the need for attention in this integration process. To investigate the role of attention we turned to multisensory distractor processing. Note that multisensory target processing is typically confounded with attention as people attend to the stimuli that they have to respond to. We designed a multisensory flanker task in which the target and distractor stimuli were both multisensory and the congruency of the features (auditory and visual) was varied orthog-onally. In addition, we manipulated participants' focus of view. Distractor congruency effects were modulated by this manipulation. When the distractor was fixated, congruency effects of both feature dimensions interacted, while congruency effects were independent when the dis-tractor was presented laterally. These results suggest that distractors presented laterally were processed at the level of features whereas distractors presented centrally (at fixation) were processed as feature compounds (i.e., objects). Multisensory integration of irrelevant stimuli is thus dependent on spatial attention.

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P1.75 Attentional modulation of multisensory event perception in a voluntary reaching movement

Loria, T., Tanaka, K., Tremblay, L., & Watanabe, K. Faculty of Kinesiology and Physical Eduction, University of Toronto and Faculty of Science and Engineering, Waseda University

Previous studies reported conflicting evidence for the hypothesis that attention influences multisensory integration (i.e., Helbig & Ernst, 2008; Talsma et al., 2010). The current study probed whether spatial-attention at the onset of a voluntary reaching movement would influence the processing and integration of task-irrelevant audio-visual stimuli. The participant's primary task was to point/reach towards one of three rectangles displayed on a touch screen monitor. At movement onset, secondary stimuli consisting of one flash (F) were presented with one or two beeps (B), that included unimodal (1F0B), congruent (1F1B), and incongruent (1F2B) conditions. After each trial, the participants reported the number of flashes, which revealed a fission illusion in the 1F2B condition (Shams et al., 2000). The secondary stimuli were deemed to be attended (i.e., within the target rectangle) or unattended (i.e., in one of the two other rectangles). Reaching movements could be towards any of the three rectangles. Accuracy in the unimodal (1F0B) and bimodal congruent conditions (1F1B) was lower when presented within the unattended vs. attended rectangle. Also, the strength of the fission illusion was reduced at the unattended compared to the

attended rectangle. An increased distance between the secondary stimuli and the attended rectangle influenced response accuracy. Indeed, both the accuracy in the unimodal and congruent conditions as well as the magnitude of the fission illusion decreased in the unattended-far compared to both the unattended-close and attended rectangles. Altogether, the results indicate a reduced perception of sensory events as well as reduced evidence of multisensory integration at unattended locations when initiating a voluntary reaching movement.

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P1.76 Self-produced walking sounds change body-representation: An investigation on individual differences and potential positive impact on physical activity

Tajadura-Jiménez, A., Zhang, L., Newbold, J., Rick, P. & Bianchi-Berthouze, N. Universidad Carlos III de Madrid & University College London

Auditory contributions to mental body-representations, and the subsequent impact on behaviour and bodily feelings, remain largely unexplored. Our studies have demonstrated changes in body-representation induced by sounds paired with bodily actions. We recently showed that the real-time alteration of sounds produced by people walking on a flat surface, so that sounds are consistent with those produced by a lighter vs. heavier body, can lead people to represent their bodies as thinner/lighter, feel happier and walk with more dynamic swings and shorter heel strikes. In the present study we investigated whether this sound-driven bodily-illusion varies according to individual differences (body weight, gender, fitness, body perceptions/aspirations), and tested the potential of this illusion to facilitate more demanding physical activity. We 142a142s142k142e142d142 142p142a142r142t142i142c142i142p142a142n142t142s142 142t142o142 142u142s142e142 142a142 142g142y142m142 142s142t142e142p142 142(142E142x142p142e142r142i142m142e142n142t142 1421142,142 142N142=14231427142)142 142o142r142 142c142l142i142m142b142 142s142t142a142i142r142s142 142(142E142x142p142e142r142i142m142e142n142t142 1422142,142 142N142=14221422142)142 142u142n142d142e142r142 142t142h142r142e142e142 142r142e142a142l142-142t142i142m142e142 142s142o142u142n142d142

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Motion-based automated coaching"). We thank Yvette Garfen for her assistance with data collection and Cintia Pechamiel Jiménez for her assistance with the gait analysis.

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P1.77 Neural circuits for visual, auditory and multisensory decision making in rats

Chartarifsky, L., Pisupati, S. & Churchland A.K. Cold Spring Harbor Laboratory

Decision-making requires assembling information from diverse sources. Existing work has begun to uncover individual areas supporting this process, but structures are usually probed using sensory signals from only one modality. Therefore, little is known about whether common versus independent circuits support decisions about, e.g., auditory vs. visual signals. Here, we aimed to determine whether there are circuits common to decisions about different sensory modalities, focusing on secondary motor cortex (FOF) and posterior striatum (pStr). FOF, a cortical area, is implicated in auditory decision-making, but little is known about its role in visual or multisensory decisions. pStr is implicated in motivation and action initiation but little is known about its role in decision-making. We trained freely-moving rats to report whether the underlying rate of a visual, auditory or multisensory stimulus was higher or lower than an abstract category boundary. Unilateral muscimol inactivation of FOF increased the overall guessing probabilities and biased rats' decisions towards the inactivated side on visual and auditory trials. Similarly, unilateral inactivation of pStr biased choices towards the inactivated side on visual and auditory trials, however, the overall guessing probability did not change. Preliminary analyses suggest that pStr, but not FOF, inactivation affected rats' optimal integration on multisensory trials. Changes in movement time to the left vs. right reward port were small and idiosyncratic across animals and sites, arguing that the observed effects were not due to a muscimol-induced motor impairment. Taken together, these results argue that FOF and pStr are part of a circuit common to decisions about multiple sensory modalities, and each area contributes differently to this process. Specifically, we suggest that FOF has a post decisional role, while pStr has a role in linking sensation to action.

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P1.78 Auditory-visual Integration during the attentional blink: an eventrelated potential study

Ching, A., Kim, J. & Davis, C. Western Sydney University

To investigate the role of attention in the integration of visual and auditory information, we used event-related potentials (ERPs) to examine integration processes in the context of the attentional blink. The attentional blink refers to an impairment in detecting a second target (T2) when it appears shortly after an initial one (T1) within a rapid serial presentation stream. We recorded and extracted ERPs following the presentation of audiovisual (AV), visual (V), and auditory (A), T2s in audio-visual presentation streams, which were presented during or after the attentional blink period (200-300 ms or 600-700ms after the onset of T1 respectively). AV Integration processes were quantified as the difference between the audiovisual ERP (AV) and the sum of the separate visual and auditory ERPs (A+V). The results showed that AV and A+V responses were more similar during the attentional blink than outside of it, suggesting that, during the attentional blink, AV integration was suppressed and visual and auditory information processed independently. AV integration (the difference between AV and A+V ERPs) occurred both before and during the time window of the P3 ERP component (300-500 ms), which is well-established as the earliest time window for attentional blink ERP effects. The fact that the attentional blink - which is thought to reflect a late-stage information bottleneck influences AV integration at early latencies suggests the action of top-down feedback mechanisms, and points to the existence of attentional blink effects that might not be observable in a unisensory paradigm.

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P1.79 The role of context in models of multisensory decision-making

Liu, Y., & Otto, T. University of St Andrews

Multisensory decisions are typically faster and more accurate than unisensory decisions. To understand the underlying processes, models of multisensory decision-making are typically fed with the behavioral performance as measured with the unisensory component signals individually. Critically, by doing so, the approach makes the so-called context invariance assumption, which states that the processing of a signal is the same whether presented in a uni- or multisensory context. However, context invariance is not necessarily true, which presents a major pitfall for any argument based on such models. As it is difficult to test context invariance directly, here, our approach is to evaluate two related

assumptions that are testable. First, we considered the role of 'stimulus' context' in unisensory decisions. We compared performance in a unisensory task in trials that either included a task-irrelevant signal in another modality, or not. We found that performance was faster but less sensitive in trials with irrelevant signals added. Hence, given this speedaccuracy tradeoff, stimulus context invariance was violated. Second, we considered the role of 'instruction context' in unisensory decisions. We presented a random trial sequences that included both auditory, visual, and combined signals. We compared performance with unisensory signals when subjects were instructed to detect targets either from only one (unisensory) or from both modalities (multisensory instruction). We found that performance was slower and with increased miss rates in multi- compared to unisensory instructions. Further, we found that the deteriorated performance was largely due to increased modality switch costs in multisensory instructions. Hence, instruction context invariance did not hold either. As both related assumptions are clearly violated, it is difficult to understand how the often hidden context invariance can be assumed true without testing. We conclude that models of multisensory decision making have to critically consider the context invariance assumption.

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P1.80 Your perceived finger orientation depends on whether you move it yourself

Fraser, L. E. & Harris, L. R. Centre for Vision Research, York University

Perception of finger orientation in the absence of vision is biased in righthanders (Fraser & Harris 2016; 2017). Here we compared perception of finger orientation during passive or active finger rotation. We hypothesized that the presence of an efference copy of the finger's movement would lead to a more precise, more accurate perception of finger orientation, compared to when the finger was passively moved.

Thirty-three right-handed participants sat with their left or right index finger placed in a slot mounted on a motor that rotated the finger, palm down, about the proximal interphalangeal joint (passive condition) or allowed them to rotate their own finger around the same axis (active condition). A horizontal mirror obscured their hand and reflected images from a monitor above. In the passive condition, the participant's finger was rotated through three "distractor" orientations to a "test" orientation; they reported perceived finger orientation by rotating a line on the screen to match their finger's orientation. In the active condition, participants rotated their finger to match three "distractor" lines, followed by a "test" line. Tested orientations were between 30° inward to 30° outward in 10° steps, with eight repetitions of each orientation.

The left hand index finger was judged as rotated more inward than the right. Active and passive accuracy was comparable for the left index finger, but active matching elicited significantly greater outward error than passive for the right finger. Precision of responses was better for the right hand compared to the left, and in the active compared to the passive task.

Our findings are consistent with research showing hand and finger orientation is systematically mislocalized in the absence of vision. Results suggest interplay between the functional specialization of the hands in righthanders, and the influence of efference copy on finger orientation perception.

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P1.81 Visuo-tactile Coherency of Self-generated Action via Surrogate Robot Affects Operator's Bodily Self-location

Inoue, Y., Yamazaki, K., Šaraiji, M. Y., Kato, F., & Tachi, S. The University of Tokyo

A surrogate robot, which has many kinds of sensors to transmit the remote environment to the operator and moves like human to replicate operator's motion, is necessary for telexistence. During teleoperation using the surrogate robot, operator can experiences the environment via the robot's sensor as if he/she is actually in there, and interact with real objects as if he/she has robot's body. However, there are still uncertain issues regarding sensory integration in the situation of telexistence, in particular the relationship visuo-tactile coherency and bodily consciousness. To investigate these, we developed an experimental telexistence system which allow subject to watch his/her own body from different view and spuriously contact it like self-touch using robot's hand either with or without tactile feedback, and conducted an behavioral experiment to evaluate the change in subjective self-location during self-touch operation. Result shows that tactile feedback from contacting position (hand) enhances the impression of getting in the robot whereas tactile feedback from contacted position (back) slightly reminds the original place where own body is on, suggesting that visuo-tactile coherency of self-generated action affects integrated feeling to the surrogate robot in telexistence.

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P1.82 Changes in hand localization are influenced by proprioception and prediction

Ruttle, J., 't Hart, B.M. & Henriques, D.Y.P. York University, Center for Vision Research

The ability to make accurate and precise goal-directed movements is based on how well we can estimate the position and motion of our limbs. These estimates rely on vision, proprioception, as well as efference-based predictions. We measure the plasticity of proprioceptive and efferent-based estimates of the hand using a series of visuomotor adaptation experiments, which involve reaching with a cursor which is rotated. We test two things. First, we assess how quickly proprioception and prediction change with altered visual feedback of the hand by measuring hand localization (of the right hand) after each training trial. Second, we can fit the multi-rate model of motor learning to the reaches, to see if any of the processes in the model predict changes in hand localization (Smith et al., 2006). To measure these changes in hand localization, participants estimated the location of the unseen hand when it is moved by the robot (passive localization) and when they generate their own movement (active localization). By comparing the differences between these hand estimates after passive (only proprioception) and active (both proprioception and efferent-based prediction) movements, we are able to tease out a measure of predicted sensory consequences following visuomotor adaptation. The trial-by-trial data suggest that proprioception recalibrates extremely fast. AIC analysis shows that this does not follow the time course of either the slow or fast process of the reach model (both p<.0008). Upon preliminary analysis prediction appears to more closely match the slow process, further investigation is required to confirm it follows the same time course. In addition, changes in prediction do not emerge nearly as fast as those for proprioception, although these efferent-based estimates continue to change with further training. These results suggest vision recalibrates both these two sources of information about hand position, proprioception and prediction, but in way that is independent.

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P1.83 Does Auditory-motor learning improve discrimination ability? Endo, N., Mochida, T., Ijiri, T. & Nakazawa, K. Department of Life Sciences, Graduate School of Arts and Sciences, The University of Tokyo Musical expertise and musical training affect auditory performance, possibly due to cognitive change, auditory learning, and auditory-motor association learning. In particular, however, to what extent auditory-motor association learning affects auditory performance has not been fully investigated. In this study, we examined whether the ability of pitch discrimination was improved by learning to associate the tone pitch with finger-gripping action.

Twenty four participants performed a discrimination task on tone stimuli having rising pitch contours. Auditory-motor learning group (AM group, n = 12) performed an auditory-motor association learning along with the discrimination task, while auditory learning group (A group, n = 12) did discrimination learning only. During the association learning, AM group manipulated a device which generates a tone whose pitch varies depending on the finger-gripping force. The duration of the experiment was 4 days, consisting of 8 blocks learning phase (2 blocks per day) and 2 blocks discrimination test phase such as pre-test (before the first block of learning phase) and post-test (after the last block of learning phase).

Differential limens (DLs) in pre-test and post-test in each group were compared by two-way ANOVA with test phase as within-subject factor and learning group as between-subject factor. The main effect of test phase was significant, while the main effect of learning group and the test phasexlearning group interaction were not significant. The results indicated that the auditory-motor learning and auditory-only learning equally improved the pitch discrimination performance.

Block-by-block changes in DLs and gripping performances during the learning phase of AM group were compared by multiple comparison. DLs were significantly improved after the second block. Gripping performances were significantly improved after the first block. These results suggested that the progressive development of auditory-motor association and the progressive improvement in discrimination performance co-occurred over the course of learning.

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P1.84 Colour-Shape Correspondences: Examining the Role of Perceptual Features and Emotional Mediation

Dreksler, N. & Spence, C. University of Oxford

Historical accounts of colour-shape correspondences usually start with Wassily Kandinsky's universal visual language of art and design, which

made extensive use of fundamental colours and forms. Kandinsky postulated an underlying and unifying correspondence between the simplest visual feature – lines – and a variety of other sensory dimensions (colour, music, emotions; Kandinsky, 1914). To Kandinsky, a triangle was yellow, a circle blue, and a square was red. Whilst this is, strictly speaking, an example of an intramodal correspondence, modern empirical work in this area has typically been grounded in the field of crossmodal correspondences: That is, bi-directional, non-arbitrary mappings between the attributes (or dimensions) of two sensory modalities, which can give rise to congruency effects in performance and are usually considered to match one another phenomenologically (Spence, 2011).

Kandinsky's correspondences and other traditional shape stimuli have been explored by various researchers through direct matching and IAT experiments (e.g., Albertazzi et al., 2013; Chen, Tanaka & Watanabe, 2015; Jacobsen, 2002; Makin & Wuerger, 2013). Only a few researchers, notably Malfatti (2014), have used larger and more controlled stimuli sets that are not limited to traditional shapes in order to examine which specific features may drive such correspondences. This paper presents a series of three online experiments that look at the perceptual (complexity, symmetry, roundedness) and affective (liking, arousal) mechanisms that may underlie colour-shape correspondences when a wider array of colours and shapes are presented to participants.

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P1.85 Mapping the topography of sensory-selective and multiple demand regions in lateral frontal cortex with combined visual, auditory and tactile fMRI

Tobyne, S.M., Noyce, A.L., Brissenden, J.A. & Somers, D.C. Boston University

Our laboratory and others have recently reported that preferences for sensory modality characterize distinct subregions of lateral frontal cortex (LFC). We previously used an auditory/visual sustained attention fMRI task to identify four bilateral interleaved regions in LFC that are selectively recruited for attention to visual or auditory stimuli (Michalka et al., Neuron, 2015); and have since replicated this finding with an auditory/visual working memory paradigm (Noyce et al., JNeurosci, 2017). These regions form separate sensory-selective intrinsic networks with posterior sensory regions. Using data from the Human Connectome Project, we recently extended these sensory-selective networks (Tobyne et al., NeuroImage, 2017). Here, we extend our auditory/visual fMRI paradigms to include tactile stimulation. While prior unimodal tactile studies have reported LFC recruitment, visual-, auditory- and tactile-selective cognitive regions remains to be investigated in concert at the individual subject level. We observe several unique tactile-biased regions of LFC that abut previously identified auditory- and visual-biased regions. We also observe several multiple demand regions that are recruited for all three modalities. The whole-brain intrinsic connectivity profiles of these LFC regions reveal that LFC ROIs possess unique fingerprints of network membership both across and within a sensory modality. Our results elucidate the complex topography of LFC and highlight the specific profiles of connectivity and task recruitment between and across sensory-selective LFC ROIs. Together, these results shed light on the complexity of LFC sensory-selective regions supporting higher-order cognition and reveal that much of an individual's LFC can be mapped using sensory-selectivity as a guiding principle.

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P1.86 Audio-tactile Crossmodal Correspondences: Listen! How does that feel?

Barnett, A. M., Walker, P. & Bremner, G. Lancaster University

Crossmodal correspondences can be defined by the appreciation of a relationship between two or more sensory channels. For instance, higherpitched sounds are perceived as being visually pointier than their lowerpitched counterparts. Given the overwhelming evidence for the existence of audio-visual crossmodal correspondences, the aim of this research was to establish whether dimensions of auditory pitch (high/low) continue to align with dimensions of angularity (pointed/rounded) when experienced by touch. In this experiment, 32 children (aged 6-9 years) and 30 adults (19-62 years) paired tones that varied in auditory pitch with objects that varied in tactile angularity. Children and adults assigned higher-/lower-pitched sounds to pointed/rounded objects, respectively. By comparison to children, adults demonstrated a stronger sensitivity to the crossmodal relationship between higher-pitched sounds and pointier objects, possibly indicating a learned component for this form of sensory perception. Findings suggest that crossmodal correspondences, at least for the relationship between auditory pitch and angularity, are less bound by sensory channels than originally considered.

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P1.87 Fast and Slow Process Integration in Visuomotor Learning: Feedback Parameters and Aging

t Hart B.M., Ruttle J., Chauhan U., Straube A., Eggert T &, Henriques D.Y.P.

Centre for Vision Research, York University, Toronto Canada

People are incredibly good at adapting their movements to altered visual feedback. In recent years it has become clear that visuo-motor adaptation does not depend on a single process. However, how multi-process motor learning depends on the task or how its' dynamics change with age is still unclear. Here we investigate how well a two-rate model (Smith et al., 2006) can account for changes in task demands, and how age affects two-rate adaptation. Participants learn to reach with a cursor to a target when the cursor's position is rotated around the start by 45° degrees. Each participant learns two rotation directions in counterbalanced order and separate parts

of the workspace. Crucially, each rotation is learned in a different task, so that we can compare model fits on data from two tasks within each participant. First, we tested if two-rate models are affected by providing continuous or terminal feedback. Terminal feedback disambiguates error size, which would benefit error-based models of motor learning. However, adaptation with terminal feedback could be explained with a single-rate process, so that continuous feedback seems better suited for studying multi-rate motor learning. Second, we tested how older and younger adults learn either an abruptly or gradually introduced rotation. The small difference between the two age groups is not significant, but this may be due to our choice of paradigm. We use the two-rate model to predict an optimal paradigm for studying differences between age groups. Our results limit how to study multi-rate motor learning, especially in older and patient populations and show that within-participant paradigms are not only possible but useful.

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P1.88 "I know that Kiki is angular": The metacognition underlying soundshape correspondences

Chen, Y.-C., Huang, P.-C., Woods, A. & Spence, C. Mackay Medical College

We examined people's ability to evaluate their confidence when making perceptual judgments concerning a classic example of sound symbolism. namely the Bouba/Kiki effect: People typically match the sound "Bouba" to more rounded patterns whereas they match the sound "Kiki" to more angular patterns instead. We used radial frequency (RF) patterns in which the features can be systematically manipulated as visual stimuli in order to induce a continuous change of the consensus in the sound-shape matchings (Chen, Huang, Woods, & Spence, 2016). Participants were asked to match each RF pattern to nonsense word "Bouba" or "Kiki" that were presented auditorily, and then rated how confident they were regarding their matching judgment. For each visual pattern, individual participant was more confident about his/her own matching judgment when it happened to fall in line with the consensual response regarding whether the pattern was rated as Bouba or Kiki. Logit-regression analyses demonstrate that participants' matching judgments and their confidence ratings were predictable by similar regression functions when using visual features as predictors. This implies that the consensus and confidence underlying the Bouba/Kiki effect is underpinned by a common process whereby visual features in the patterns are extracted and then used to match the sound following rules of crossmodal correspondences. Combining both matching and confidence measures therefore allows

researchers to explore and quantify the strength of crossmodal associations in human knowledge.

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P1.89 Imagery clarifies confusion in the crossed-hands deficit

Lorentz, L., Unwalla, K. & Shore, D.I. Department of Psychology, Neuroscience & Behaviour. McMaster University

Localizing our sense of touch requires integrating internal, body-based cues, with external, predominantly visual cues. Placing the hands in a crossed posture puts the reference frames for these cues into conflict, producing a crossed-hands deficit (CHD; decreased accuracy in a tactile temporal order judgment (TOJ) task when the hands are crossed). Removing visual information by blindfolding reduces the CHD, presumably by degrading the external reference frame, and therefore decreasing the conflict. However, blindfolding does not eliminate the deficit. This suggests that participants may still have access to visual information: perhaps they spontaneously imagine their crossed hands. Since visual imagery relies on activation of brain areas similar to those used in visual perception, this imagery may provide access to the visual (external) reference frame. To test this hypothesis, we asked blindfolded participants to imagine their hands uncrossed, even though they were crossed, while performing a tactile TOJ task. Information in the external reference frame should now be compatible with that in the internal reference frame, resulting in reduced conflict, and consequently, a decreased CHD. Participants completed three ordered blocks: uncrossed, crossed, and crossed with uncrossed imagery instructions. Participants also completed several self-report measures of mental imagery ability. Instructions to imagine the hands uncrossed produced a numerical trend toward a smaller deficit. However, the more interesting finding was a positive correlation between imagining ability and the size of the crossed-hands deficit. Those with strong mental imagery had a significantly larger CHD, providing an example of another individual difference affecting this measure. Future theorizing on the internal-external reference frame translation must consider, or control for, the influence of mental imagery

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P1.90 Implied tactile motion: Localizing dynamic stimulations on the skin Merz, S.,Meyerhoff, H.S., Spence, C. & Frings, C. University of Trier

We report two experiments designed to investigate how implied movement during tactile stimulation influences localization on the skin surface. Understanding how well tactile sensations can be localized on the skin surface is an important research question for those working on the sense of touch. Interestingly, however, the influence of implied motion on tactile localization has not been investigated before. Using two different experimental approaches, an overall analogue pattern of localization shifts to the visual and auditory modality is observed. That is, participants perceive the last location of a dynamic stimulation further along its trajectory. In Experiment 1 (N = 38), participants judged whether the last vibration in a sequence of three vibrations was located closer to the wrist or elbow. In Experiment 2 (N = 21), participants indicated the last location on a ruler which was attached to their forearm. We further pinpoint the effects of implied motion on tactile localization by investigating the independent influences of motion direction and perceptual uncertainty. Taken together, these findings underline the importance of dynamic information in localizing tactile stimuli on the skin. These results also indicate modality specificdifferences in the localization of approaching vs. receding stimuli, hinting at different functions of localization in different modalities.

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P1.91 Perception as Cognition: Beyond the Perception/Cognition Distinction

Hipolito, I. University of Wollongong

This paper argues that perceiving belongs within the cognitive fold, not outside of it. It reviews and rejects the rationale for drawing sharp distinction between perception and cognition introduced by modular theories of mind. Modular theories assume that perception has an informational encapsulated character that marks it out as different from other forms of cognition. These theories will be rejected on the explanatory power of predictive processing, which dissolves the perception/cognition distinction. Predictive processing accounts however have been challenged for embracing a problematic, overly intellectualist vision of cognition across the board. It is shown that, even if we accept the full force of such critiques, there is a way to construe the predictive processing proposal such that it leaves space for a more nuanced account of perception – one that embraces the right degree of intellectualism and provides a way of retaining some important insights from the failed modular theories of perception. Finally, it is shown that reading predictive processing theories through this lens does not give us reason to think of any form of perceiving as non-cognitive – rather, it enables us to see all forms of perception as forms of cognition.

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P1.92 Mental Rotation of Digitally-Rendered Haptic Representation

Tivadar, R.I., Rouillard, T., Chappaz, C., Knebel, J.F., Turoman, N., Anaflous, F., Roche, J. & Murray, M.M. University Hospital Center and University of Lausanne

Owing to neuroplasticity of visual cortices, several functions can be retrained after loss of vision using sensory substitution. Tactile information, for example, can support functions such as reading, mental rotation, and exploration of space. Extant technologies typically rely on real objects or pneumatically-driven renderings and thus provide a limited library of stimuli to users. New developments in digital haptic technologies now make it possible to actively simulate tactile sensations (www.hap2u.net). We studied such a new type of technology that renders haptic feedback by modulating the friction of a flat screen through ultrasonic vibration of varying amplitude to create the sensation of texture when the screen is actively explored. We reasoned that participants should be able to create mental representations of letters presented in normal and mirror-reversed haptic form without the use of any visual information, and to manipulate such representations in a mental rotation task. Normally sighted, blindfolded volunteers were trained on randomly assigned pairs of two letters (L and P or F and G) on a haptic tablet. They then felt all four letters in normal or mirror-reversed form at different rotations (0°, 90°, 180°, and 270°) and indicated their perception of the form by mouse button presses. We observed a prototypical effect of rotation angle on performance (i.e. greater deviation from 0° resulted in greater impairment), consistent with mental rotation of these haptically-rendered objects. We likewise observed generally slower and less accurate performance with mirror-reversed stimuli. Our findings extend existing research in multisensory integration by indicating that a new technology with simulated active haptic feedback can support the generation and spatial manipulation of mental representations of objects. This technology may thus offer an innovative solution to the

mitigation of visual impairments and to the training of skills dependent on mental representations and their spatial manipulation.

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P1.93 Audio-visual multiple object tracking: integration differences with age

Harrar, V., Roudaia, E. & Faubert, J. School of Optometry, Université de Montréal

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 assessed whether dynamic sounds congruent with visual targets could facilitate tracking in a 3D-MOT task in 35 young (18-36) and 35 older adults (60-75). Participants tracked one or two targetspheres among identical distractor-spheres while they moved inside a 3D cube for 8 s. at an individually-adjusted speed. In the no sound condition, targets were identified by a brief colour change, but were then indistinguishable from the distractors during the movement. In the audiovisual condition, each target was accompanied by a sound that moved congruently with the target. In the audiovisual control condition, the movement of the sound was incongruent with the target's movement, the sound accompanied a distractor sphere. The amplitude of the sound varied with distance from the observer, the pitch of the sound varied with vertical elevation, and inter-aural amplitude difference varied with azimuth. In young adults sound with targets improved tracking, but only with a single target. Older adults showed no effect of sound overall, although older adults who were tracking targets at higher speeds were more likely to benefit from sound than the rest of the sample. Together, these results suggest that audiovisual binding in dynamic stimuli may be limited to a single target and may be less common in ageing.

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P1.94 Proprioceptive Distance Cues Restore Perfect Size Constancy in Grasping, but Not Perception, When Vision Is Limited Chen, J.C., Sperandio, I.S. & Goodale, M.A.G.

University of Western Ontario

Our brain integrates information from multiple modalities in the control of behavior. When information from one sensory source is compromised, information from another source can compensate for the loss. What is not clear is whether the nature of this multisensory integration and the reweighting of different sources of sensory information are the same across different control systems. Here, we investigated whether proprioceptive distance information (position sense of body parts) can compensate for the loss of visual distance cues that support size constancy in perception (mediated by the ventral visual stream) versus size constancy in grasping (mediated by the dorsal visual stream), in which the real-world size of an object is computed despite changes in viewing distance. We found that there was perfect size constancy in both perception and grasping in a fullviewing condition (lights on, binocular viewing) and that size constancy in both tasks was dramatically disrupted in the restricted-viewing condition (lights off; monocular viewing of the same but luminescent object through a 1-mm pinhole). Importantly, in the restricted-viewing condition, proprioceptive cues about viewing distance originating from the nongrasping limb (experiment 1) or the inclination of the torso and/or the elbow angle of the grasping limb (experiment 2) compensated for the loss of visual distance cues to enable a complete restoration of size constancy in grasping but only a modest improvement of size constancy in perception. This suggests that the weighting of different sources of sensory information varies as a function of the control system being used.

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Poster Session 2 – June 16th 3:15pm – 4:45pm

P2.1 Virtual Reality modulates Vestibular Brain Responses

Gallagher, M., Dowsett, R. & Ferrè, E.R. Royal Holloway University of London

Virtual reality (VR) has become increasingly popular in the past decade. Key to the user's VR experience are multimodal interactions involving all senses. However, sensory information for self-motion is often conflicting in VR: while vision signals that the user is moving in a certain direction with a certain acceleration (i.e. vection), the vestibular organs provide no cues for linear or angular acceleration. To solve this conflict, the brain might downweight vestibular signals. Here we recorded participants' physiological responses to actual vestibular events while being exposed to VR-induced vection. We predicted that exposure to a few minutes of linear vection would modulate vestibular processing. Vestibular-evoked myogenic potentials (VEMPs) were recorded during exposure to either a randomly moving (no-vection condition) or expanding field of dots (vection condition). A significant enhancement in VEMPs P1-N1 peak-to-peak amplitude was observed in the vection condition compared to the no-vection condition, for vestibular stimuli activating the right cortical vestibular projections. Our results suggest that exposure to VR modulates brain responses to vestibular stimuli. This supports the idea of a sensory re-weighting occurring in VR.

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P2.2 Cybersickness in virtual reality partially explained by temporal binding window width

Sadiq, O. & Barnett-Cowan, M. University of Waterloo

Virtual reality (VR) is a computer-generated simulation that largely manipulates visual surroundings that are updated when the observer moves in the real world. VR often causes sickness (known as cybersickness) in users, perhaps due to temporal and spatial discrepancies between multisensory cues from the virtual and real environments. While spatial discrepancies are largely resolved in current head mounted display VR experiences, temporal discrepancies still persist and are often in the order of ~22ms or more from head movement to visual updating. Here we sought to assess whether individual differences in the ability to bind multisensory cues in time within a "temporal binding window" (TBW) are related to

cybersickness. We tested 11 participants in two different tasks. The first task involved two temporal order judgements, 1) an audio-visual (AV) and 2) an audio-active head movement (AHMa) task where participants were presented with sound paired with a visual or head movement stimulus at different stimulus onset asynchronies. The second task involved exploration of two VR experiences for 30 mins each where participants' sickness was quantified every 2 minutes on the fast motion sickness scale and also at the end using the simulator sickness questionnaire (SSQ). Results show strong positive correlations between SSQ scores and TBW width from the AV task, indicating those with wider AV TBWs as more susceptible to cybersickness. Correlations of SSQ and AHMa TBWs were non-significant. We conclude that while the CNS integrates information from all sensory modalities to navigate through VR experiences, our data suggests that individual differences in processing the relative timing of visual cues play a dominant role in predicting cybersickness. Our results will help develop novel assessment tools to predict cybersickness and hopefully can be used to develop new tools to reduce sickness tailored to individual differences in processing multisensory information.

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P2.3 Sensitivity to visual gain modulation in head-mounted displays depends on fixation

Moroz M., Garzorz I., Folmer E. & MacNeilage, P. University of Nevada, Reno

A primary cause of simulator sickness in head-mounted displays (HMDs) is the rendering of visual scene motion that does not match head motion. Agreement between visual scene motion and head motion can be quantified based on their ratio which we refer to as visual gain. We suggest that it is useful to measure perceptual sensitivity to visual gain modulation in HMDs (i.e. deviation from gain=1) because conditions that minimize this sensitivity may prove less likely to elicit simulator sickness. In prior research, we measured sensitivity to visual gain modulation during slow, passive, fullbody yaw rotations and observed that sensitivity was reduced when subjects fixated a head-fixed target compared with when they fixated a scene-fixed target. In the current study, we investigated whether this pattern of results persists when 1) movements are faster, active head turns, and 2) visual stimuli are presented on an HMD rather than on a monitor. Subjects wore an Oculus Rift CV1 HMD and viewed a 3D scene of white points on a black background. On each trial, subjects moved their head from a central position to face a 15 deg eccentric target. During the head movement they fixated a point that was either head-fixed or scene-fixed, depending on condition. They then reported if the gain applied to the visual scene motion

was too fast or too slow. Gain on subsequent trials was modulated according to a staircase procedure to find the gain change that was just noticeable. Sensitivity to gain modulation during active head movement was reduced during head-fixed fixation, similar to what we observed during passive whole-body rotation. We conclude that fixation of a head-fixed target is an effective way to reduce sensitivity to visual gain modulation in HMDs, and may also be an effective strategy to reduce susceptibility to simulator sickness.

Acknowledgments: Research was supported by NIGMS of NIH under grant number P20 GM103650.

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P2.4 A common cause in the phenomenological and sensorimotor correlates of body ownership

Samad, M., Parise, C., Keller, S. & Di Luca, M. Oculus Research

The feeling that our limbs belong to our body is at the core of bodily selfconsciousness. Over the years, limb ownership has been assessed through several types of measurements, including guestionnaires and sensorimotor tasks assessing the perceived location of the hand with a visualproprioceptive conflict. Some studies report a correlation between the phenomenological and sensorimotor measures, whereas others report no relationship. This inconsistency prevents a unified operational definition of limb ownership. We sought to jointly record these two measurements to assess whether they originate from the same process. To that end, we used state-of-the-art hand tracking technology in virtual reality to induce ownership over a virtual limb while we parametrically manipulated spatial and temporal incongruences. Participants reported the subjective ownership and pointed to a target without seeing their hand to assess perceived hand location. Results show a surprisingly tight correlation between phenomenological and sensorimotor measures. We frame limb ownership as a multisensory integration problem, whereby the brain computes the probability that visual and proprioceptive signals have a common cause and thus that the visually presented hand belongs to one's body - and based on this determines the perceived hand location considering the reliability of the sensory signals. The outcome of the computation thus determines both the position of the hand and the strength of the ownership on which the subjective feeling should be based. We show that a Bayesian Causal Inference model closely captures human responses in both tasks, reconciling a fragmented literature and suggesting that body ownership can be well explained by a normative framework that has also been shown to account for a variety of other multisensory phenomena.

Acknowledgments: We acknowledge the support of a postdoc fellowship of the German Academic Exchange Service (DAAD)

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P2.5 The balance of evidence: Estimating the influence of contributors to cybersickness

Weech, S., Varghese, J.P., Duncan, R.E. & Barnett-Cowan, M. University of Waterloo, Department of Kinesiology

Despite the wide-ranging potential of virtual reality (VR), use of the technology is currently limited to enthusiasts. One major cause for this limited uptake is cybersickness, consisting of symptoms such as nausea and disorientation, which prevents adoption and reduces the likelihood that the user continues to use VR. The causes of related phenomena (e.g., seasickness, visually-induced motion sickness) have been subject to theorizing for several hundred years, but progress on a solution is slow. New approaches are required if society is to benefit from the promise of VR. Most studies of cybersickness focus on the impact of a single factor (e.g., balance control, vection), while the contributions of other factors are overlooked. However, accounting for the vast inter-individual variability in cybersickness will require the contributions of multiple predictors to be estimated. Here, we characterize how the complex relationship between balance control, vection susceptibility, and vestibular thresholds relates to cybersickness. We collected indices from a battery of sensory and behavioural tests, predicting that we would find an independent influence of each factor, and a complex multivariate interaction. In a 3 hour session, participants conducted tasks that measured balance control, responses to vection, and vestibular sensitivity to self-motion. While vestibular thresholds and most balance control measures demonstrated a low predictive value, the results showed that cybersickness is significantly predicted by a combination of vection responses and perturbed-stance balance control measures. In particular, high vection susceptibility appears to have a protective effect against cybersickness. These results complement a long line of research on vection and visually-induced motion sickness. The findings improve our understanding of an enduring obstacle to the adoption of VR, and will guide the development of therapeutic interventions. We address the prospect that genetic factors might play a role in cybersickness, and discuss the challenges involved in answering this question.

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P2.6 Rubber hand/foot illusion in older adults

Teramoto, W. & Hide, M. Kumamoto University

Studies have reported that several perceptual and cognitive functions are altered with age. However, little is known about multisensory processing involved in bodily perception. The present study investigated older adults' body representations and its link to their sensorimotor functions using rubber hand illusion (RHI) and rubber foot illusion (RFI). Twenty-four older adults participated in this study. Participants viewed a rubber hand or foot stimulated in synchrony or asynchrony with their own hidden hand or foot for 5 min. RHI and RFI were assessed with guestionnaires, proprioceptive drift, and onset times. Sensorimotor functions were independently assessed with the Timed Up and Go (TUG) test, which is one of the clinical tools for examining functional mobility and fall risk in older adults. The participants were divided into two groups based on their TUG scores. Results showed that subjective ratings for body ownership and location were not different in terms of body parts or in the TUG groups. However, proprioceptive drift was larger for foot than hand, especially for the group with a relatively poor TUG performance. Additionally, the onset time was shorter for this group than for the group with relatively better TUG performance. These results suggest that the relative importance of visual over proprioceptive information to localize older adults' own body parts can be changed depending on the body part and that it may be closely linked to decline in sensorimotor functions related to gait and balance.

Acknowledgments: This study was supported by JSPS KAKENHI Grant (S) (No. 16H06325) and (B) (No. 26285160).

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P2.7 An audio game to help children and young peopler in developing cognitive associations between sounds and words

Setti,W., Cuturi, L. F., Cocchi, E. & Gori,M. Italian Institute of Technology

Spatial memory is based on the capability to memorize and retrieve the locations of objects in the environment. In order to remember the position of an object, the individual can rely on its intrinsic characteristics such as the shape, colour or smell. Here we investigate how the auditory modality might affect spatial memorization, based on two different associations: between identical sounds and between a sound and its related concept. We focused on how these association processes develop during the lifespan. To this

aim, we tested children (6-8 y.o) by implementing an audio memory test in the form of a game (i.e. the classical memory game), with two experimental conditions. In the first condition (semantic sounds), each participant is asked to find pairs of animal calls. In the second condition (semantic words), the task is to pair each animal call with a recorded voice that reproduces animal's name. The sounds were played through a device composed of 25 loudspeakers covered by tactile sensors. A cardboard grid was placed on its surface. Each time a participant found a pair, the experimenter covered the slots with cardboards. Two parameters were evaluated: the score reached by the participants in the two conditions and the number of tries employed to complete the game. Our results show a tendency to perform worse in the semantic words condition as participants reached a lower score and ended the game with a higher number of tries. The participants have more difficulties in pairing the animal call and the name. We discussed this result in terms of the role of human growth and experience since children learn word meanings gradually by adding more features to their lexical entries. The game could be used as a rehabilitative paradigm to structure the link between sounds and concepts related to them

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P2.8 Audio-haptic cue integration across the lifespan

Scheller, M., Proulx, M.J. & Petrini, K. University of Bath

Optimal integration of multisensory information has frequently been shown to benefit perception by speeding up responses and increasing perceptual precision and accuracy. These effects, however, are often demonstrated in young adults, and to a lesser extent in older adults or children, with a scarcity of studies examining how optimal integration changes across the lifespan. Furthermore, most studies have used different tasks and approaches to measure multisensory processing adaptation over large age ranges, making it difficult to compare between them. Here, by using the same adaptive size discrimination task and a cross-sectional design, we investigated how audio-haptic cue integration performance changes over the lifespan in children, younger adults, and older adults (age range spanning from 7 to 70years). Participants were asked to give size discrimination judgements for physical objects of different sizes using either touch or hearing (unimodal) or both at the same time (bimodal). Discrimination thresholds were assessed for unimodal and bimodal stimulus presentation and compared with predictions from a maximum likelihood estimation (MLE) model. Results show that children do not make use of audio-haptic multisensory size information until around 13 years of age, while both younger and older adults benefit from integrating multisensory

information, leading to increased precision. These results corroborate and extend the findings from previous studies that used different approaches, showing that children only gain from multisensory integration late in childhood, but that its benefits are preserved until later in life. It further suggests that integration of non-visual information, which becomes increasingly important with declining visual function later in life, allows individuals to effectively make use of redundant information, thereby offering an advantageous compensatory mechanism for declining sensory function.

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P2.9 Mechanisms of audiovisual integration in younger and healthy older adults

Jones, S.A., Beierholm, U. & Noppeney, U. Centre for Computational Neuroscience and Cognitive Robotics, University of Birmingham

As we age, multisensory integration becomes increasingly critical for effective interaction with the environment. Some studies have shown greater multisensory benefits for older than younger adults. Others have suggested that older adults weight sensory signals suboptimally when compared to the predictions of Maximum Likelihood estimation.

Combining psychophysics, fMRI, multivariate pattern analysis (MVPA) and Bayesian Causal Inference (BCI) modelling, we investigated the computational operations and neural mechanisms mediating audiovisual integration of spatial signals in younger and older adults. In a spatial ventriloquist paradigm, we presented younger and older adults with synchronous auditory and visual signals at various levels of spatial conflict and reliability. Participants located the sounds in a selective attention task or judged whether auditory and visual signals came from a common source.

Our results revealed no significant effects of ageing on spatial location or common source judgments, as indicated by response choices or the parameters of a BCI model fitted individually to each participant's responses. However, older participants' response times for common source judgment and related selective attention tasks were significantly affected by the spatial congruence of the stimuli. This suggests that while older adults' ability to integrate and respond to audiovisual stimuli is preserved (given sufficient time), they may be recruiting additional resources when arbitrating between integration and segregation of stimuli. We discuss these results in relation to a subsequent fMRI study, in which we presented younger and

older participants with a similar ventriloquist task and applied MVPA to decode audiovisual spatial representations across the cortical hierarchy.

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P2.10 Age-related brain changes in multisensory representation of hand movement

Landelle, C., Sein, J., Nazarian, B., Anton, J.L., Félician, O. & Kavounoudias, A. LNSC

To perceive self-movements, the central nervous system relies on multiple sensory inputs including touch and muscle proprioception. We have previously identified a change in the relative contribution of this senses to perceive hand movements due to a greater alteration in muscle proprioception in the elderly1. The present study investigated whether these perceptual changes correlate with neural plastic changes using fMRI.

To this end, illusory sensations of right hand rotations were induced in young and old adults by stimulating separately the two modalities at two intensities (Low and High). The proprioceptive stimulation was induced by a mechanical vibration applied to their wrist muscle, while the tactile stimulation consisted in a textured disk rotating under their hand. Participants underwent a first experiment to estimate their ability to discriminate the velocity of hand movement illusions before being tested inside a 3-Tesla MRI scanner.

Results show that a common sensorimotor network is activated in both groups during movement illusions of tactile and proprioceptive origin: the contralateral primary sensorimotor cortices, bilateral inferior parietal lobule, supplementary motor area, insula and ispsilateral cerebellum. However, group comparisons revealed a broadening of this network in the ipsilateral hemisphere for older adults, which correlates with declining individual performance to perceive illusion velocity from proprioceptive but not tactile origin.

The present findings show that age-related changes in kinesthetic perception from proprioceptive origin may be at least partly due to a central alteration of the interhemispheric balance between the primary sensorimotor regions in the elderly.

1. Landelle et al. NeuroFrance 2017

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P2.11 Vestibular Sensitivity in Older Adults and Individuals with Age-Related Hearing Loss

Campos, J.L., Gnanasegaram, J., Harris, L.R., Cushing, S., Gordon, K., Haycock, B. & Gabriel, G. Toronto Rehabilitation Institute, University Health Network

Several recent epidemiological studies have identified a reliable association between age-related hearing loss (ARHL) and an increased risk of falling in older adults. However, the exact nature of this relationship remains unclear. One possibility is that there are parallel declines in the sensitivities of both the auditory and vestibular systems in individuals with ARHL. Because the auditory and vestibular organs both use mechanical displacement of hair cells to sense sound and head movement/gravity respectively, are located in close proximity to each other, and inputs from both systems travel to the brain via the vestibulocochlear nerve, it is possible that age-related changes are occurring due to a common cause within an individual. Here we tested this hypothesis by investigating whether older adults with ARHL also have an impaired ability to perceive passive self-motion in the dark compared to their age-matched peers without hearing loss. Younger adults (18-35) and older adults with normal hearing (65+) and older adults with ARHL participated. A motion platform passively rotated (pitch) and translated (heave) participants. A two-interval forced choice task was implemented in which participants identified in which of the two intervals they were moved. Detection thresholds were determined using an adaptive psychophysical staircase procedure. Measures of hearing ability (pure-tone thresholds), vestibular function (video head impulse test, vestibular evoked myogenic potential), and balance (posturography) were also conducted. Results showed that older adults had a reduced sensitivity in detecting heave motion compared to younger adults. Older adults with ARHL demonstrated a reduced sensitivity in detecting heave and pitch movements compared to normal hearing peers. Older adults with ARHL also demonstrated less stable standing balance. Overall, these results indicate that age-related hearing loss may be associated with poorer-than-normal vestibular sensitivity, which may underlie an increased risk of falls.

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P2.12 Two Signals For Hand Localization – No Optimal Integration t Hart, B.M. & Henriques, D.Y.P.

Centre for Vision Research, York University, Toronto, Canada

Knowing where your limbs are, is important for evaluating movements with internal models - and for planning new movements. When people are asked to localize their unseen hand after a movement, they have two nonvisual signals available: predicted sensory consequences, based on an efference copy of the motor command, as well as felt hand position, or proprioception. Using a maximum likelihood estimate, people would integrate these two signals with weights depending on each signals' reliability, and the combined estimate would have higher reliability than each signal individually, evident as a lower variance. While we can't measure hand location estimates based on predicted sensory consequences in isolation, we can measure hand location estimates based on proprioception alone and on the two signals combined. In a previous paper ('t Hart & Henriques, 2016) we found no evidence of maximum likelihood estimation as the variance of the responses was approximately equal. However, there were very few trials, and a relatively small group of participants, potentially obscuring effects. Here we have almost triple the data per participant and have over 80 younger participants. In this larger dataset there is again no evidence of maximum likelihood estimation. In a group of older participants (N=20, age: 65+) the variance in responses is not larger suggesting there is no significant effect of age on estimates of limb position and this group also shows no signs of optimal integration. So far, it seems that the brain does not integrate predicted sensory consequences with actual sensory information similarly to how the brain integrates signals from two sensory modalities. This might be required to compare integrated sensory-only estimates of hand location with efferencepredicted estimates in order to update internal models during motor learning.

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P2.13 Changes in the perception of the peripersonal space during pregnancy

Cardini, F., Fatemi-Ghomi, N., Gooch, V. & Aspell, J.E. Anglia Ruskin University

The space immediately surrounding our body – i.e. 'peripersonal space' (PPS) - is important, as it is where we interact with stimuli in the external world. Recent studies have shown that the PPS boundaries are malleable. Therefore with our study we aimed at investigating whether the PPS changes during pregnancy, a critical stage in life, when extremely rapid changes occur in the body size and shape. Given the rapidity of these changes, we expected that as pregnancy advances, the PPS should expand, reflecting an updated mental representation of one's body that, as

the abdomen increases, makes external stimuli, initially perceived as being outside of the PPS, to be perceived closer, within the PPS.

To this aim, we tested 37 pregnant women and 19 non-pregnant women three times: at the 20th and at 34th week of the gestational period and 8 weeks postpartum (same time intervals for the control group). To assess the PPS boundaries we used a well-established audio-tactile task (Canzoneri et al., 2012).

By comparing the boundaries between groups we found that whereas at the first and the third testing period no differences in the PPS size were observed, in the second period – i.e. at the advanced stage of pregnancy – the pregnant participants' PPS was larger than the controls'.

To conclude, during pregnancy our brain adapts to the sudden change in body size, by expanding the representation of the space around us, possibly in order to protect the vulnerable abdomen from bumping against objects.

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P2.14 Multisensory influences in locomotor development

Schmuckler, M. A. University of Toronto Scarborough

Currently there exists compelling evidence that, in adults, successful locomotion through the world requires significant multisensory information and control. The most straightforward example of such multisensory control of locomotion arises in research investigating aspects of visually-guided locomotion, exploring peoples' abilities to navigate around obstacles, over barriers, and through apertures. More recently researchers have been exploring the developmental trajectories of such multisensory control, examining young toddlers' and children's abilities to guide themselves around a cluttered environment, as well as the ability to make use of and integrate an array of multisensory inputs during locomotion. Work in my lab examines toddlers' (14- to 24-month-old children), children's (3 to 6 years) and adults' walking skill as a function of widely varying multisensory information and visual-guidance requirements. One series of experiments explored the impact on toddlers' walking skill of providing additional haptic information via object carriage when having to cross or not cross barriers in ones' path. A subsequent study extends these investigations by examining the impact on toddlers' and adults' gait of varying proprioceptive inputs while navigating along paths requiring varying forms of visual-guidance. In this case, proprioceptive inputs were manipulated by either loading or not

loading the limbs (applying 15% of body weight to the legs). Visualguidance was manipulated by requiring walking under conditions of free locomotion (wide pathway, no obstacles), constrained locomotion (narrow pathway, no obstacles), and guided locomotion (narrow pathway, obstacles). These studies converge in finding that, from early in life, toddlers show significant multisensory influences on their locomotion in the world, on both a gross behavioral level as well as on low-level kinematic parameters of gait.

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P2.15 Maintained cross-modal control in aging: Unimodal and cross-modal interference follow different lifespan trajectories

Hirst, R.J., Allen, H.A. & Cragg, L University of Nottingham

In two experiments we assessed whether unimodal and cross-modal interference follow similar patterns of development and deterioration across the lifespan and whether unimodal and cross-modal interference occur at similar levels of processing. In experiment 1, children (n=42; 6-11), younger adults (n=31; 18-25) and older adults (n=32; 60-84) performed unimodal and cross-modal Stroop tasks. Colours and words could be congruent, incongruent but mapped to the same response (stimulus-incongruent) or incongruent and mapped to different responses (response-incongruent), thus separating interference occurring at early (sensory) and late (response) processing levels. Unimodal interference followed a U-shape lifespan trajectory, however, older adults maintained the ability to ignore cross-modal distraction. Unimodal interference produced accuracy decrements due to response interference whilst cross-modal interference did not. In experiment 2, we compared the effects of auditory and visual cross-modal distractors in children (n=52; 6-11 years), young adults (n=30; 22-33 years) and older adults (n=30; 60-84 years). Neither type of crossmodal distraction followed the U-shape trajectory seen in unimodal conditions. Older adults maintained the ability to ignore both visual and auditory cross-modal distractions. Unimodal and cross-modal interference appear to follow different lifespan trajectories and this may, in part, be due to differences in the processing level at which interference takes effect.

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P2.16 Altered Audiovisual Processing and Perception following a Loss of Inhibition in the Multisensory Cortex of the Rat

Schormans, A.L. & Allman, B.L. University of Western Ontario

Multisensory processing is a hallmark of the mammalian cortex; however, it remained uncertain what neuropharmacological factors contribute to the integration and accurate perception of multisensory stimuli. In the present study, we sought to investigate for the first time the role of local inhibition on cortical audiovisual processing and perception. In vivo extracellular electrophysiology recordings were completed across the layers of the rat lateral extrastriate visual cortex (V2L) — a region known to respond to both auditory and visual stimuli - before and after the local micro-infusion of the GABA-A antagonist, Gabazine. Ultimately, the effect of blocking inhibition on audiovisual processing was assessed at the level of local field potentials and spiking activity in response to auditory and visual stimuli presented alone or in combination. Subsequently, we used a separate group of rats trained on an audiovisual temporal order judgment (TOJ) task to determine the effect of local Gabazine micro-infusion in the V2L cortex on the ability to perceive the relative timing of audiovisual stimuli presented at various stimulus onset asynchronies. Using our established laminar analyses, the loss of inhibition in V2L resulted in a 4x increase in sensory responsiveness irrespective of stimulus modality. Surprisingly, despite an increase in peak latency to both auditory and visual stimuli, only the response to visual stimulation showed a delayed onset. Consistent with these electrophysiological results, a loss of inhibition in the V2L cortex during the TOJ task altered the rats' audiovisual perception, such that the visual stimulus needed to be presented well before the auditory stimulus in order for the stimuli to be perceived as having been presented simultaneously (vehicle: 3.9 ± 7.9 ms; Gabazine: 45.5 ± 11.9 ms). Taken together, our results suggest that a loss of cortical inhibition has significant implications on audiovisual processing and perception.

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P2.17 Pre-attentive and Perceptual Audiovisual Temporal Processing in Rats Lacking the Autism Candidate Gene CNTNAP2 Scott, K., Schormans, A., Schmid, S. & Allman, B.

Western University

Pre-attentive and perceptual integration of multisensory information is necessary for appropriate interactions with our environment. In individuals with autism spectrum disorders (ASD), impairments in lower-level audiovisual processing can impact higher-order functions that rely on the

ability to integrate complex auditory and visual signals across time. At present, the neural basis for these behavioural deficits remains unresolved. Preclinical animal models could help to reveal the molecular mechanisms of lower-level audiovisual processing impairments if they can first show high face validity for the ASD-related behavioral deficits. To that end, we assessed both pre-attentive and perceptual audiovisual processing in rats lacking the autism candidate gene CNTNAP2 (Cntnap2-/- rats) using translational behavioural paradigms. Pre-attentive audiovisual processing was examined utilizing the acoustic startle response (ASR) and its modulation by an auditory, visual, or audiovisual stimulus (i.e., prepulse) which occurred before the acoustic startle-eliciting stimulus. In addition, the rats' ability to perceive the relative timing of audiovisual stimuli was assessed using a temporal order judgement (TOJ) task, consistent with studies on humans. As expected, the Cntnap2-/- rats exhibited a general impairment in prepulse attenuation of the ASR compared to age-matched wildtype controls. Interestingly, Cntnap2-/- rats, like wildtypes, showed a greater level of prepulse inhibition when the audiovisual prepulse was presented compared to the unimodal prepulse conditions; findings which indicate that the brainstem of the knockout rats was still able to integrate auditory and visual stimuli. At the perceptual level, Cntnap2-/- rats did not show a deficit in their ability to judge the relative order of the auditory and visual stimuli, which was consistent with previous studies in the autistic population performing the TOJ task with simple flash-beep stimuli. Taken together, these preliminary results highlight the validity of Cntnap2-/- rats as a preclinical model for studying audiovisual processing associated with ASD.

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P2.18 Facilitation of speech-in-noise perception from visual analogue of the acoustic amplitude envelope

Yuan, Y. & Lotto, A. J. University of Florida

It is well-known that an accompanying visual presentation of a talker can increase the accuracy of perception of speech in noise. Whereas some of the benefit of the visual stimulus may be disambiguating particular phonetic segments (e.g., the lip closure during a /b/), it is also possible that the dynamic movement of the mouth provides an analogue of the acoustic amplitude envelope. Information about the amplitude envelope could allow the listener to better track the speech signal in the noise. To test this hypothesis, listeners were presented spoken sentences in babble noise either in auditory-only or auditory-visual conditions. In this case, the visual stimulus was a sphere that increased and decreased in size synced to the

amplitude of the speech signal (the envelope was extracted prior to being mixed with the babble noise). A significant improvement in accuracy in the auditory-visual condition was obtained even though there was no visual representation of phonetic information. These results provide evidence that visual representations of the amplitude envelope can be integrated online in speech perception. Not only do these data speak to the underlying benefits of visual presentations of talkers but opens up other possible techniques of improving speech in noise perception. In particular, the current technique can provide more veridical information about the amplitude envelope than can be inferred from visual displays of mouth/face kinematics.

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P2.19 Frontal lobe network contributions to auditory and visual cognition Noyce, A.L., Tobyne, S.M., Michalka, S.W., Shinn-Cunningham, B.G. & Somers, D.C. Boston University

Human caudolateral frontal cortex (LFC) is often characterized as domaingeneral or multiple-demand, due to its recruitment in a wide range of cognitive tasks (e.g. Duncan 2010, Fedorenko 2013). However, our laboratory has recently used fMRI to demonstrate that a direct contrast of visual and auditory attention (Michalka 2015) or visual and auditory working memory (Noyce 2017 robustly identifies a number of discrete sensorybiased regions in caudolateral frontal cortex. Three bilateral visual-selective areas, superior and inferior precentral sulcus (sPCS and iPCS) and mid inferior frontal sulcus (mIFS) are interleaved with three bilateral auditoryselective areas, the transverse gyrus bridging precentral sulcus (tgPCS), caudal inferior frontal sulcus/gyrus (cIFS/G), and frontal operculum (FO). These frontal structures also participate in sensory-specific functional networks with posterior visual (IPS/TOS) and auditory (STG/S) regions.

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P2.20 Recalibration of vocal affect by a dynamic or static face Baart, M., Keetels, M. & Vroomen, J.

Department of Cognitive Neuropsychology, Tilburg University, the Netherlands

Perception of vocal affect is influenced by the concurrent sight of an emotional face. We demonstrate that the sight of an emotional face also can induce recalibration of vocal affect. Participants were exposed to dynamic videos of a 'happy' or 'fearful' face in combination with a sentence with ambiguous prosody. After this exposure, ambiguous test sentences were rated as more 'happy' when the exposure phase contained 'happy' instead of 'fearful' faces. This auditory shift likely reflects recalibration that is induced by error minimization of the inter-sensory discrepancy. When the prosody of the exposure sentence was non-ambiguous and congruent with the face, aftereffects went in the opposite direction, reflecting adaptation. In a second experiment, we showed that recalibration could also be observed when the visual stimulus seen during exposure was static (i.e., a still frame of the video) rather than dynamic. Importantly, aftereffects in both the dynamic and static AV exposure conditions were larger than in a visual-only exposure condition where no cross-modal learning was possible. Our results demonstrate, for the first time, that perception of vocal affect is flexible and can be recalibrated by dynamic and static visual information.

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P2.21 Optimal multisensory integration precedes optimal time estimation Murai, Y. & Yotsumoto, Y.

University of California, Berkeley

Time is an amodal perceptual attribute that can be defined by any sensory modality. Since events in the outer world often generate multiple sensory signals, our brain estimates event time efficiently by collating multisensory information in a statistically optimal way (Hartcher-O'Brien et al., 2014). As well as the information redundancy occurring from one event, our brain utilizes the statistical structure of multiple events to perceive time optimally: the current percept is biased toward the mean of previous stimuli in a Bayesian manner (central tendency; Jazayeri & Shadlen, 2010). The present study investigates how these two strategies interact and shape an optimal timing behavior. In the experiment, we measured the timing sensitivity and the central tendency by the time discrimination task and the time reproduction task, respectively, for unisensory (auditory or visual) and multisensory stimuli. In the discrimination task, participants judged whether the standard duration (640 ms) was longer or shorter than the comparison duration (450-900 ms), and the timing sensitivity was defined by the slope of best-fit psychometric function. In the reproduction task, participants reproduced the stimulus duration (450-900 ms), and the central tendency

was defined by the slope of the linear regression of the reproduced durations to the stimulus durations. In both tasks, the sensory uncertainty was systematically manipulated by adding noise. Psychophysical results demonstrated that the sensory uncertainty impairs the timing sensitivity and increases the central tendency bias, and that the multisensory timing improves both performance metrics compared to the unisensory timing. We computationally modeled the multisensory timing performance from experimentally obtained unisensory data, and revealed that the optimal multisensory integration precedes the Bayesian time estimation causing the central tendency. Our findings suggest that our brain incorporates the multisensory information and prior knowledge in a statistically optimal manner to realize precise and accurate timing behavior.

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P2.22 When does the brain integrate signals from vision and audition in line with the predictions of maximum likelihood estimation?

Meijer, D. &Noppeney, U. University of Birmingham, UK

Multisensory perception is regarded as one of the most prominent examples for optimal human behaviour. Human observers are thought to integrate sensory signals weighted in proportion to their sensory reliabilities into the most reliable percept as predicted by maximum likelihood estimation (MLE). Yet, evidence to date has been inconsistent. Given the recent surge of interest in the limits and requirements of optimal human behaviour, we performed two experiments. The first study aimed to investigate motivation and training as potential factors that may influence whether or not observers integrate signals (MLE-)optimally in an audiovisual spatial localization task. Results indicated that half of the participants did not deviate significantly from MLE-based predictions, whereas the other half of the participants weighted the visual signals more than was predicted by reliability-weighted integration. Critically, we found no significant main effect for prior training or motivational reward: i.e. (sub-)optimal participants were spread equally across the groups. For the second study, we made some minor changes to the experimental design and found an increase in the number of participants that behaved (MLE-)optimally. Future studies are required to reinvestigate whether we may observe an effect of training or reward with the improved experimental design.

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P2.23 Revealing audiovisual integration with the drift diffusion model

Murray, C.A., Tahden, M.A.S., Glicksohn, A., Larrea-Mancera, S., Seitz, A.R. & Shams, L.

University of California, Los Angeles

When an object produces sensory stimulation in more than one modality, the detection and discrimination of the object can improve because multiple sources of information can be exploited by the nervous system to perform the task. This advantage has manifested both as improvement in reaction time (RT) and in accuracy. If this improvement in performance exceeds the probability sum of the accuracy or RT in unisensory conditions, it cannot be attributed to a statistical advantage due to redundancy; previous studies have then interpreted it as evidence of sensory integration. The vast majority of multisensory integration studies have historically focused on analyzing evidence of integration based on either accuracy or RT (but see Drugowitsch et al, 2014; Rach, Diedrich, Colonius, 2011, Thelen, Talsma, & Murray, 2015). Here we present results that show that this approach may be inadequate in identifying and characterizing multisensory integration. The speed-accuracy trade-off may mask the advantage of multisensory integration (Drugowitsch et al, 2014,), and therefore, to uncover the integration, a model that takes both accuracy and RT into account should be employed. For this purpose, we employed a Bayesian, hierarchical variant of a drift diffusion model (Wiecki, T.M., Sofer, I., & Frank, M.J., 2013). The model utilizes accuracy and RT data to fit decision parameters that differentiate between decision-making components, including stimulus discriminability and participant bias. In a task that required participants to detect auditory, visual, and audiovisual pulses, model results indicate drift rate, which is correlated to stimulus discriminability, was higher for audiovisual pulses compared to both auditory and visual pulses. We will also present model results from other tasks. The results indicate that participants may be integrating the stimuli, even though neither accuracy nor RT data alone provide evidence of integration.

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P2.24 How input modality and visual experience affect the neural encoding of categorical knowledge

Mattioni, S., Rezk,M., Cuculiza Mendoza, K., Battal, C., Bottini, R., van Ackeren, M., Oosterhof, N.N. & Collignon, O. UcL- Université catholique de Louvain Is conceptual knowledge implemented in the brain based on representation that are abstracted from any sensory features, or, alternatively, relies on the activation of representations that are bounded to the input modality and based on sensory experience? To test these conflicting views, we used fMRI to characterize the brain responses to 8 conceptual categories presented acoustically in sighted and early blind individuals, and visually in a separate sighted group. We observed that the right posterior middle temporal gyrus (rpMTG) is the region that most reliably decode categories and selectively correlate with conceptual models of our stimuli space independently of input modality and visual experience. However, rpMTG maintained separate representational format between audition and vision, suggesting distinct representational geometries across the senses. We also observed a robust enhancement in decoding auditory categories in the occipital cortex of blind individuals. Interestingly, this effect was lateralized to the right hemisphere. We then correlated the representational geometries extracted from the sighted group in vision with those from separate groups of blind and sighted in audition in regions that typically show categorical preference for faces (FFA), tools (LO) and scenes (PPA). We found a correlation between the visual and the auditory representational geometry of the stimuli in both hemispheres for the blind, but only in the left hemisphere for the sighted. All together these results demonstrate how input modality and sensory experience impact on the neural implementation of categorical representations and highlight hemispheric asymmetries in their expression.

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P2.25 Short and long-term visual deprivation leads to adapted use of audiovisual information for face-voice recognition Moro, S.S., Hoover, A.E.N. & Steeves, J.K E.

Centre for Vision Research, York University Person identification is essential for everyday social interactions. We quickly

Person identification is essential for everyday social interactions. We quickly identify people from cues such as a person's face or the sound of their voice. A change in sensory input, such as losing one's vision, can alter how one uses sensory information. We asked how people with only one eye, who have had reduced visual input during postnatal maturation of the visual system, use faces and voices for person identity recognition. We used an old/new paradigm to investigate unimodal (visual or auditory) and bimodal (audiovisual) identity recognition of people (face, voice and face-voice) and a control category, objects (car, horn and car-horn). Participants learned the identity of 10 pairs of faces and voices (Experiment 1) and 10 cars and horns (Experiment 2) and were asked to identify the learned face/voice or car/horn among 20 distractors. People with one eye were more sensitive to

voice identification compared to controls viewing binocularly or with an eyepatch. However, both people with one eye and eye-patched viewing controls use combined audiovisual information for person identification more equally than binocular viewing controls, who favour vision. People with one eye were no different from controls at object identification. The observed visual dominance is larger for person compared to object identification, indicating that faces (vision) play a larger role in person identification and that person identity processing is unique from that for objects. People with long-term visual deprivation from the loss of one eye may have adaptive strategies, such as placing less reliance on vision to achieve intact performance, particularly for face processing.

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P2.26 An Electroencephalography Investigation of the Differential Effects of Visual versus Auditory Distractors on Crossmodal Temporal Acuity Kwakye, L.D., Hirabayashi, K.K., Barnes-Scott, Z. & Papadakis, S.L. Oberlin College

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 either a visual distractor or auditory distractor task. We found that increasing the perceptual load of both distractor tasks 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 in association with a visual distractor 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. We found 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. Ongoing data collection investigates whether increasing auditory load will lead to alterations in auditory processing, thus suggesting a modality-specific mechanism for disruptions in crossmodal temporal acuity. Preliminary data

analysis suggests different changes in the neural processing of audiovisual stimuli with increases in auditory load as compared to visual load. This line of research serves to illuminate the neural networks that underlie the interaction between attention and multisensory integration.

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P2.27 Perceived simultaneity of audio-visual events depends on the relative stimulus intensity.

Horsfall, R.P., Wuerger, S.M. & Meyer, G.F. University of Liverpool

Purpose. Simultaneity judgements (SJ) and temporal order judgements (TOJ) are often used to characterise audio-visual integration mechanisms. The resulting points of subjective simultaneity (PSS) have been shown to be uncorrelated, suggesting different underlying mechanisms. The multisensory correlation detector (MCD) model (Parise & Ernst, 2016) accounts for this lack of correlation by assuming identical early processing mechanisms but different task-specific weightings. The aim of our experiments was to explore the effect of the relative intensity of the unimodal signals on the PSS.

Methods. 34 observers (20-69 y.o.a.) performed both SJ and TOJ tasks with identical flash/bleep stimuli (100ms) with varying stimulus onset asynchronies (-200ms AV to +200 VA) and two flash intensities (1.1cd/m2 or 366cd/m2). In the TOJ task, participants judged whether the audio or the visual stimulus came first; in the SJ task, whether the stimuli occurred simultaneously or separately. The PSS was defined as the SOA corresponding to maximum of the SJ curve, and the 50% point of the TOJ curve.

Results. (1) Consistent with previous reports, no correlation was found between the PSSs of the SJ and TOJ tasks. (2) Flash intensity had an effect: the PSS shifts from 20.9ms (dim) to 7.6ms (bright) in the SJ, and from 17.2ms (dim) to -7.4ms (bright) in the TOJ. (3) The effect of intensity is asymmetric around the PSS and is more pronounced for visual leading stimuli. (4) When an early non-linearity in the unimodal signals is added to the MCD model, the intensity-dependent shift in the PSS is predicted, but the observed asymmetry is not captured.

Conclusion. Our findings constrain possible models of intensity-dependent audio-visual integration mechanisms by ruling out low-level mechanisms as the sole explanation. We speculate that attentional enhancement of the visual signal by the auditory signal may play a role.
Acknowledgments: I would like to thank Kielan Yarrow for help with the model fitting.

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P2.28 Hearing that voice and seeing that face: the role of non-affective characteristics in person identification.

Jicol, C., Little, A.(1), Petrini, K.(1,2) & Proulx, M.J.(1,2) (1,2) Joint senior authors University of Bath

Most research on how vocal and facial cues can be correlated has considered affective content as the most influential factor determining these associations. However, due to expertise in vocal and facial integration in day-to-day life, individuals may also associate

certain non-affective characteristics of one cue with those of the second. especially in cases where only one modality is available (e.g. vocal when talking on the phone). The current study investigated whether non-affective face characteristics predicted associations with voices based on the same characteristics perceived in voices varying in emotion. First, in a rating study, 10 neutral voice utterances and 30 neutral faces were rated by 110 participants on masculinity, femininity, attractiveness, trustworthiness, age and body mass. In a matching study, these faces and voices were presented to another 49 participants who were asked to match each face with one voice. A second matching study used happy and sad versions of the same 10 voices and asked another 112 participants to perform the same matching task as per the neutral study. For both studies, the perceived characteristics (e.g. masculinity and attractiveness) well correlated between most matched faces and voices, for neutral, happy and sad voices for male and female judges. Results showed consistent patterns of associations, indicating that non-affective cues can cause specific faces to be matched with certain voices. Some pairings were dependent on the emotion of the voice and were consistent across genders, while others only varied across genders, but not emotion. Overall, males made most matching choices based on body mass and females on age. These findings have relevance for the development of sensory substitution devices aimed at blind and visual impaired individuals as they point at the most relevant information used to form a certain facial representation given a certain voice.

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P2.29 Development of cultural differences in emotion perception from faces and voices

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Recent studies have demonstrated cultural differences in multisensory emotion perception from faces and voices. Tanaka et al. (2010) showed that Japanese people are more tuned than Dutch people to vocal processing in adults. The current study investigated how such a cultural difference develops in children and adults. In the experiment, Japanese and Dutch participants observed affective expressions of both Japanese and Dutch actors. A face and a voice, expressing either congruent or incongruent emotions, were presented simultaneously on each trial. Participants judged whether the person is happy or angry. Results in incongruent trials showed that the rate of vocal responses was higher in Japanese than Dutch participants in adults, especially when in-group speakers expressed a happy face with an angry voice. The rate of vocal responses was very low and not significantly different between Japanese and Dutch 5-6-year-olds. However, it increased over age in Japanese participants, while it remained the same in Dutch participants. These results suggest the developmental onset of cultural differences in multisensory emotion perception.

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P2.30 Sensory Rate Perception – Simply the sum of its parts?

Motala, A. & Whitaker, D. Cardiff University

Previous experiments utilising the method of sensory adaptation have presented evidence towards a temporal 'rhythm aftereffect'. Specifically, adapting to a fast rate makes a moderate test rate feel slow, and adapting to a slow rate makes the same moderate rate feel fast. The present work aims to deconstruct the concept of rhythm and clarify how exactly the brain processes a regular sequence of sensory signals. We ask whether there is something special about 'rhythm', or whether it is simply represented internally by a series of 'intervals'. Observers were exposed to a sensory rhythm of either auditory or visual temporal rates (a 'slow' rate of 1.5Hz and a 'fast' rate of 6Hz), and were tested with single empty intervals of varying durations. Results show adapting to a given rate strongly influences the temporal perception of a single empty interval. This effect is robust across both, interval reproduction and two-alternative forced choice methods. These findings challenge our understanding of temporal rhythms and suggest that adaptive distortions in rhythm are, in fact, distortions to repeatedly presented uniform intervals composing those rhythms.

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P2.31 Multi-modal representation of visual and auditory motion directions in hMT+/V5.

Rezk, M., Cattoir, S., Battal, C. & Collignon, O. Catholic University of Louvain (UCL), Belgium

The human middle temporal area hMT+/V5 has long been known to code for the direction of visual motion trajectories. Even if this region has been traditionally considered as purely visual, recent studies suggested that hMT+/V5 could also selectively code for auditory motion. However, the nature of this cross-modal response in hMT+/V5 remains unsolved. In this study, we used functional magnetic resonance imaging to comprehensively investigate the representational format of visual and auditory motion directions in hMT+/V5. Using multivariate pattern analysis, we demonstrate that visual and auditory motion direction can be reliably decoded inside individually localized hMT+/V5. Moreover, we could predict the motion directions in one modality by training the classifier on patterns from the other modality. Such successful cross-modal decoding indicates the presence of shared motion information across the different modalities. Previous studies used successful cross-modal decoding as a proxy for abstracted representation in a brain region. However, relying on series of complementary multivariate analysis, we unambiguously show that brain responses underlying auditory and visual motion direction in hMT+/V5 are highly dissimilar. For instance, our results demonstrated that auditory motion direction patterns are strongly anti-correlated with the visual motion patterns, and that the two modalities can be highly discriminated based on their activity patterns. Moreover, representational similarity analyses demonstrated that modality invariant models poorly fitted our data while models assuming separate pattern geometries between audition and vision strongly correlated with our observed data. Our results demonstrate that hMT+/V5 is a multi-modal region that contains motion information from different modalities. However, while shared information exists across modalities, hMT+/V5 maintains highly separate response geometries for each modality. These results serve as a timely reminder that significant cross-modal decoding is not a proxy for abstracted representation in the brain.

Acknowledgments: Fonds national de la recherche scientifique (FNRS)

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P2.32 Changes in resting-state connectivity in deaf individuals after learning a second (sign) language

Cardin, V., Kremneva, E., Komarova, A., Vinogradova, V., Davidenko, T., Turner, B. & Woll, B. University of East Anglia

Studies of neural reorganisation as a consequence of early deafness show that regions in the superior temporal cortex, which are usually involved in speech processing in hearing individuals, are involved in sign language processing in deaf individuals. Posterior STC (pSTC) is also recruited for visual working memory processing in deaf individuals. This is accompanied by increased resting-state connectivity between pSTC and frontoparietal regions in deaf individuals.

Here we are interested in understanding whether early deafness results in a reorganisation of brain regions and networks involved in language learning. Specifically, we investigate whether there is an increase in resting-state connectivity between pSTC and frontoparietal regions due to second language learning. Language can be produced and perceived in several modalities -- spoken, signed, written.

However, most language research, including that of language learning, focuses on the study of spoken languages. With this approach, it is not possible to disentangle which processes are related to the sensorimotor processing of the spoken and written language signal, and which, if any, reflect abstract linguistic processing. Here we studied changes in resting state connectivity in groups of deaf individuals as they learned, in a naturalistic setting, a second sign language (L2). Participants were deaf signers of Russian Sign Language who enrolled in a course equivalent to Level 1 British Sign Language. Resting state fMRI scans were collected before, during and after the BSL course.

Preliminary results showed no difference in connectivity between pSTC and frontoparietal regions after language learning. Instead, there was an increase in connectivity between anterior temporal and frontal regions in deaf individuals after learning a sign language as an L2. These findings are in agreement with previous studies of spoken L2 learning, suggesting that these regions are involved in language learning independently of language modality.

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P2.33 Sight restoration in congenitally blind individuals: multisensory perception for action execution

Senna, I., Pfister, S. & Ernst, M. Ulm University, Germany

In our daily life we easily integrate vision with other sensory signals (e.g., proprioception) to plan and guide actions. When a systematic error is introduced, for instance by means of prism goggles shifting the apparent location of a target, humans can still reach for the target by easily recalibrating the visuo-motor system. In the present study we investigated whether newly-sighted individuals (i.e., born with bilateral cataract, and surgically treated after years of visual deprivation) are able to recalibrate the sensory-motor systems and thus minimise the systematic error.

Compared to typically developing individuals, who quickly adapted to the visual shift, newly-sighted were less able to recalibrate the sensorimotor system: they partially reduced the error, but they did not fully adapt to the visual shift. The present finding cannot be explained just by the fact that newly-sighted individuals have lower visual acuity than controls. First of all, the ability to adapt to the visual shift correlated not only with visual acuity, but also with time since surgery. Moreover, blurring vision in sighted controls did not impair controls' ability to adapt to the visual shift: although such procedure made the recalibration rate slower, controls still adapted more and faster than newly-sighted individuals. Finally, some cataract patients could be tested right before and right after surgery, and their performance did not improve immediately after surgery, despite a significant improvement of their visual acuity.

These results show that newly sighted individuals can only partly make use of visual feedback to correct motor performance. Such ability is not present immediately after surgery, but it seems to require time (and thus some sensory-motor experience) to develop.

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P2.34 Increased recruitment of rSTS for tactile motion processing in early deaf individuals

Scurry, A.N., Huber, E. & Jiang, F. University of Nevada, Reno

Upon early sensory deprivation, the remaining intact modalities often exhibit cross-modal reorganization. For instance, early deaf (ED) individuals reveal recruitment of auditory cortex for visual motion processing as compared to normal hearing (NH) controls. Previous studies of compensatory plasticity in early deaf individuals have tended to focus on visual spatial processing with less attention given to the tactile modality. Therefore in the current study, we aimed to examine the effects of early auditory deprivation on tactile motion processing. An experimenter simulated 4 directions of tactile motion on the right index finger of 5 ED and 5 NH controls who were asked to detect infrequent trial blocks (less than 10%) that contained repeated motion direction. Using a modified population receptive field (pRF) analysis method that assumed a one dimensional Gaussian sensitivity profile on the tactile motion direction, we characterized tactile motion responses in anatomically-defined primary and secondary somatosensory cortices (SI and SII, respectively), primary auditory cortex (PAC), and functionallydefined superior temporal sulcus (STS) based on visual motion responses. As expected, similar direction-selective responses were found within SI and SII between the two groups. We also found significant but minimal responses to tactile motion within PAC for all subjects. While ED individuals show significantly larger recruitment of right STS (rSTS) upon tactile motion stimulation, there was no evidence of directional tuning in this region as revealed by pRF analysis. Greater recruitment of rSTS upon tactile motion is in line with findings from animal studies investigating cortical reorganization in multisensory areas. The presence of tactile motion responses with no clear directional tuning in rSTS suggests a more distributed population of neurons dedicated to processing tactile spatial information as a consequence of early auditory deprivation.

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P2.35 Elucidating responses to non-visual motion cues in hMT+ of early blind and sighted adults.

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In sighted individuals, BOLD activity can be observed in a middle temporal cortical region, known as hMT+, in response to moving visual stimuli. There is evidence to suggest that this region may be a multimodal area, with fMRI studies showing BOLD responses in hMT+ to both tactile and auditory

motion cues in addition to visual responses (Hagen et al., 2002; Poirier et al., 2005). Furthermore, research has shown that hMT+ responds to auditory and tactile motion in early blind individuals (Jiang, Stecker, & Fine, 2014; Matteau, Kupers, Ricciardi, Pietrini, & Ptito, 2010). However, a more recent study showed that areas within hMT+ in sighted individuals which respond to moving visual stimuli are not recruited when processing tactile motion information if BOLD activation is mapped on individual subjects (Jiang, Beauchamp, & Fine, 2015). We wanted to assess whether this would also be the case for auditory and tactile motion cues in early blind individuals, as hMT+ responds to both tactile and auditory motion cues in this cohort. Our study also aimed to elucidate whether modulation of BOLD activity in hMT+ would be observed when auditory and tactile motion cues are presented together. In addition, we compared how this region responds to non-visual motion input in sighted subjects. Conjunction analyses revealed that activation in response to tactile and auditory motion cues overlaps within hMT+ in early blind individuals at the single subject level. In the sighted group, BOLD activity was not observed in hMT+ in response to auditory motion stimuli. Modulation of BOLD activity was found in hMT+ when audio-tactile motion cues were presented to early blind adults. The results of this study provide evidence of latent multisensory inputs to visual cortex and also inform the design of sensory substitution devices by demonstrating how multisensory cues can impact the effectivity of these devices.

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P2.36 Peripheral, task-irrelevant sounds activate contralateral visual cortex even in blind individuals.

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Recent findings suggest that peripheral, task-irrelevant sounds elicit activity in contralateral visual cortex, as revealed by a sustained positive deflection in the event-related potential (ERP) over the occipital scalp contralateral to the sound's location (McDonald et al., 2013). This Auditory-evoked Contralateral Occipital Positivity (ACOP) appears between 200–450ms after sound onset, and is present even when the task is entirely auditory and no visual stimuli are presented at all. Here, we investigate whether this crossmodal activation of contralateral visual cortex is mediated by visual experience. To this end, ERPs were recorded in 12 early blind subjects during an unimodal auditory task. Participants sat 180 cm away from a set of speakers and listened to a stream of sounds that were presented in random order and at unpredictable times (variable inter-stimulus-interval). The auditory stream included task-irrelevant noise bursts delivered from the left or right sides (i.e. ±25° eccentricity) and 1000Hz target tones delivered from the center (i.e. 0° eccentricity; similar to McDonald et al., 2013). Participants were instructed to press a button every time they heard a central target tone, while ignoring the peripheral noise bursts. The EEG analysis focused on the ERPs triggered by the task-irrelevant noise bursts. It was found that these noise bursts elicited an ACOP, indicating that peripheral sounds can enhance neural activity in visual cortex in a spatially specific manner even in visually deprived individuals.

In conclusion, the cross-modal activation of contralateral visual cortex triggered by peripheral sounds does not require any visual input to develop. Our results are in line with a growing body of literature showing a strong and reliable response to sounds in the primary visual cortex of blind individuals (Amedi et al., 2007, Lane et al., 2015, Bedny et al., 2011, Roder et al., 2002, Kujala et al., 1995, Focker et al., 2012).

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P2.37 Audio-Spatial Representation is Altered in Patients with Central Scotoma

Ahmad, H., Setti, W., Capris, E., Facchini, V. & Gori, M. Italian Institute of Technology (IIT), Genova, Italy

Sound localization is a skill developed in blind individuals in order to perceive space around them (Collignon et al. 2005, Renier, Collignon et al. 2005, Striem-Amit and Amedi 2014). This plastic change is developed in auditory cortex after the loss of visual modality. Macular Degeneration (MD) is a retinal disorder creating "blind spots" on retina that results in cutting visual inputs at corresponding visual representations. This study investigates if the absence of vision due to a central scotoma (blind spot) induces a change in audio spatial modality in patients having central MD. We investigated sound localization in 16 MD patients (age range 14-87 years; mean age = 66.875 years) suffering from central vision loss, and a control group of 16 age-matched (p > 0.05) sighted controls using an array of 25 haptic blocks with loudspeakers in the center, arranged in the form of a matrix. Subjects were asked to fixate at the central block of matrix while localizing sounds coming from other speakers (central or peripheral) of the matrix. We found that patients with central vision loss are more frequently attracted towards the central speakers compared to peripheral ones (p < p

0.05), whereas sighed group tend to perceive sounds all over the arena (P > 0.05) i.e. both central and peripheral speakers. These results supports our hypothesis that sound is attracted towards the blind zones. We suggest that this attraction of sounds towards scotoma could be a result of plasticity that recruits audio inputs on visual cortex after vision loss. We are performing EEG experiments to further support the idea that the recruitment of the visual cortex by audition after loss of vision is a fast plasticity mechanism that starts immediately after vision loss to support multisensory integration.

Acknowledgments: Claudio Campus and Guilio Sandini

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P2.38 Influence of visual experience on auditory spatial representation around the body

Aggius-Vella, E., Campus, C. & Gori, M. Istituto Italiano di Tecnologia (IIT)

There is still a diatribe about the role of vision in calibrating auditory sense during spatial tasks. Some studies showed that blind people perform better than sighted people in localizing sounds (Collignon et al., 2006), while others found that the lack of vision leads to a spatial deficit in the auditory spatial bisection task (Gori et al., 2014). Our previous research found that sighted people perform better the auditory spatial bisection task in the frontal space, compared to the rear space. We discussed these results as the evidence of the important role of vision in calibrating hearing, providing a different auditory representation of the rear space, where vision is not available. To confirm that the difference between performances in the two spaces was due to vision, in the current study we investigated how the lack of vision affects audio spatial metric representations in the frontal and rear space by testing blind participants. Sighted and early blind participants were involved in a spatial bisection task and in two control tasks: a minimum audible angle and a temporal bisection task. As expected, both groups showed no differences between frontal and back space in the minimum audible angle and in the temporal bisection task. Contrarily, in the spatial bisection task, sighted and blind individuals behaved differently in the two spaces. While sighted subjects performed better in the frontal space than in the rear, no difference between spaces was found in the early blind group. Our results are in agreement with the idea that vision is important in developing auditory spatial metric representation. Moreover, we showed for the first time that the role of vision is specific for spaces where vision is naturally available, providing evidences that rear and frontal space are differently coded by brain on the base of different sensory input.

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P2.39 A comparison of neural responses to visual stimulation in congenitally deaf, neonataly deafened and hearing cats measured in MRI

Levine, A.T., Butler, B.A. & Lomber, S.G. The University of Western Ontario

Normal brain development depends on early sensory experience. In the case of hearing loss, unutilised brain regions are seen to undergo plasticity and process signals from intact sensory inputs. Experiments with congenitally deaf human or animal subjects show evidence of improved abilities in peripheral visual motion detection and spatial localization. Such heightened behavioral performances in the visual domain are facilitated by compensatory plasticity occurring in deprived brain regions. Evidence of crossmodal plasticity is widely documented throughout the literature, however, not as much is known about plasticity occurring unimodaly (i.e. whether visual cortical representations of visually-evoked activity are altered in the deaf).

To address this, non-invasive high field functional magnetic resonance imaging (fMRI) was used in lightly anesthetized congenitally deaf, neonatally deafened, and hearing cats. BOLD percent signal change was measured during the presentation of a whole field visual circular flashing checkerboard, extending 16 degrees into the peripheral field. Fixation was confirmed by visually assessing the gaze of the cat through the scanner bore. Across the three groups, patterns of activation within thalamic as well as primary visual areas are compared to describe differential effects of early sensory loss across different levels of the visual processing hierarchy. Moreover, the degree to which auditory cortical regions show visuallyevoked BOLD activity is compared. These whole-brain functional data are the first of their kind, and will further our understanding of both crossmodal and unimodal plasticity in the deaf brain.

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P2.40 Consonant-Order Reversals in the McGurk Combination Illusion

Gil-Carvajal, J. C., Dau, T. & Andersen, T.

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Humans can integrate auditory and visual information when perceiving speech. This is evident in the McGurk effect, in which a presentation of e.g. auditory /aba/ and visual /aga/ leads to the audiovisually fused percept /ada/. With the pairing of auditory /aga/ and visual /aba/, however, the illusion takes the form of a combination percept of either /abga/ or /agba/. Here, we investigated how audiovisual timing influences the perceived order of the consonants in the McGurk combination. Stimuli were recorded with the consonants /g/ and /b/ using vowel-consonant-vowel (VCV) utterances with two syllabic contexts. First, the "internal timing" was studied by articulating the consonant to either emphasize the closing phase (VC-V) or the opening phase (V-CV). This produced cross-modally asynchronous consonants while maintaining synchrony of the vowels. Auditory /ag_a/ dubbed onto visual /a_ba/ was mostly heard as /agba/ whereas auditory /a_ga/ dubbed onto visual /ab_a/ was mostly heard as /abga/. Hence, syllabic context largely determined the perceived consonant order. Second, the effect of audiovisual stimulus onset asynchrony (SOA) was examined at five different SOAs, ranging from 200 ms auditory lead to 200 ms visual lead. The results showed no effect on the perceived consonant order but audiovisual SOAs influenced the strength of the illusion. Furthermore, we found that the window of integration is highly asymmetric for combination illusions and that the direction of the asymmetry depends on the perceived consonant order. We interpret the results as indicative of feature based audiovisual integration where formant transitions and aspirations are integrated separately.

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P2.41 A probabilistic model for modulated speech encoding in the McGurk effect

Karthikeyan, G., Plass, J., Ahn, E., Rakochi, A., Stacey, W. & Brang, D. University of Michigan

Viewing a speaker's lip articulations during speech can affect what a listener perceives. In the McGurk effect, a mismatch between visual information extracted from lip articulations (e.g., the viseme /ga/) and auditory information extracted from the speech signals (e.g., the phoneme /ba/) results in the listener perceiving a "fusion" percept not present in either the auditory or visual signals (e.g., the phoneme /da/). Previous research has demonstrated that this effect involves a network of areas including posterior fusiform face areas, visual motion area MT, and temporal auditory

areas, with lipreading information present even in early auditory areas. Nevertheless, the role of these separate regions in generating the McGurk effect remains poorly understood. Here, we utilize deep learning algorithms to examine whether probabilistic models of electrocorticographic (ECoG) activity in these regions can account for typical perceptual experiences observed in the McGurk effect. Patients were presented auditorily, visually, or audiovisually (congruent or incongruent) with four different phonemes. We used Convolutional Neural Networks (CNNs) to determine the probability with which the identity of each phoneme could be decoded based on auditory-alone trials, visemes, and congruent and incongruent audio-visual trials. The individual decoding probabilities of the auditory alone trials and visemes were then used to calculate a probability for comparison with the decoding probability of congruent and incongruent audio-visual trials across different brain regions and frequency bands. This analysis results in a computational model for the McGurk Effect that incorporates the unique contributions of multiple neural regions (MT, pSTS, STG) and neurophysiological mechanisms (low-frequency oscillations and local synaptic or spiking activity) in order to explain how multisensory speech modulates neural activity to produce modulated speech perception.

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P2.42 Word Frequency and the McGurk Effect

Dorsi, J., Rosenblum, L. & Chee, S. UC Riverside

In the McGurk effect, visual speech can alter the perception of concurrently presented auditory speech (McGurk & MacDonald, 1976). For example, when auditory 'Ba' is dubbed onto visual 'Va' participants will often 'hear' the visual stimulus 'Va'. Prior work has demonstrated that McGurk effects are stronger when they form words than when they form non-words (e.g. Brancazio, 2004). This work demonstrates that lexical information can influence the McGurk effect. The current project seeks to further quantify this influence by evaluating whether word frequency bears on the effect. A pilot experiment used 20 word pairs, each comprised of words differing only in the initial consonant, /B/ or /V/ (e.g. auditory "Base" + visual "Vase"). The data from this pilot study showed a robust correlation between the McGurk effect and the lexical frequency of the auditory and visual words, such that the McGurk effect is stronger when the visual word is more common (e.g. visual "Vase" [high frequency] produces more McGurk percepts than does visual "Versed" [low frequency]). The current work seeks to replicate this correlation with a larger set of words and generalize this finding to other initial consonant McGurk stimuli. Additionally, the current project examines how lexical frequency interacts with McGurk 'fusion' effects, in which the

perceived consonant is different from both the auditory and visual stimuli (i.e. auditory /Bore/ + visual /Gore/ is perceived as /Door/; see McGurk & MacDonald 1976).

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P2.43 Synchronized visual and olfactory stimuli induce VR-based out-ofbody experiences

Yasushi A. & Hiroki O. Tokyo Institute of Technology

An Out-of-Body Experience (OBE) is a phenomenon in which a feeling arises as if a person sees herself/himself from the outside of the physical body. OBE is a phenomenon mainly occurring under special conditions. For example, Blank and colleagues reported that it causes OBE by giving electrical stimulation to "right angular gyrus". Ehrsson and colleagues have been reported that by using VR, synchronization of visual stimuli and tactile stimuli causes OBEs. However, as far as the authors know, OBEs caused by synchronizing visual stimuli and sensory stimuli other than tactile stimuli have not been reported. In this study, we evaluated whether OBEs by synchronization of visual and olfactory stimuli occur by analyzing the evaluation of a questionnaire. To examine whether olfactory stimuli elicit OBEs, we conducted two conditions; one is that the olfactory and visual stimuli are presented synchronously, the other is that these stimuli are presented asynchronously. We also conducted a replication for the Ehrsson's experiment. The questionnaire used for the evaluation consists of three test items (Q 1 to 3) and 7 control items (Q 4 to 10) and was analyzed by ANOVA whether there is a significant difference between the test and the control item. As a result of the experiment, there was a significant difference between the test items and the control items in the synchronous condition (p < 0.01). When comparing the synchronous and asynchronous condition, the scores of the test items in the synchronous condition tended to be significantly higher or significantly higher than that of the asynchronous condition (Q 1, 2: p < 0.10, Q 3: p < 0.01). And the results of replication were consistent with previous studies. Our results suggest that olfactory stimulation induce an Out-of-Body Experience.

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P2.44 Olfactory input influences intranasal somatosensory perception

Karunanayaka P., Lu J. & Sathian K. Department of Radiology, Penn State College of Medicine

It is well known that odor perception is influenced by intranasal somatosensory input, e.g. with sniffing. A considerable body of earlier work has shown that, when pure olfactory inputs are presented monorhinally to humans, the side of stimulation cannot be localized reliably, while concomitant intranasal somatosensory stimulation via air-puffs or sniffs enables reliable localization. However, it is not clear whether olfactory input modulates perception of intranasal somatosensory stimuli. Here we investigated this issue in healthy humans with normal olfactory function, using the odorant phenyl ethyl alcohol (rose) and somatosensory stimulation with weak air-puffs delivered intranasally. Visual cues were used to inform participants to briefly hold their breath while weak air-puffs were delivered to either nostril, in the presence or absence of the odorant. In a two-alternative forced choice, participants indicated whether their perception of the air-puff was in the left or right nostril. Consistent with prior research, localization accuracy was essentially at chance in a control condition when the odorant was delivered alone, without an air-puff. Yet, the combination of the odorant and a weak air-puff in the same nostril significantly improved localization accuracy for the air-puff, relative to presentation of the air-puff without the odorant. This enhancement of somatosensory localization was absent when the air-puff and odorant were presented to different nostrils, arguing against a non-specific alerting effect of the odorant. Thus, olfactory input does indeed influence processing of intranasal somatosensory stimuli. It remains for future work to establish the locus of this multisensory interaction and to clarify the underlying neural mechanism.

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P2.45 Party music and drinking decisions: multisensory effects of alcoholrelated cues

James, T.W. & Nikoulina, A. Indiana University

Decisions are based on integration of sensory signals from multiple sources that make up the environmental context. Individuals with alcohol use disorder show hyper-reactivity to alcohol-related sensory cues from different sensory sources, however, little is known about how these individuals integrate multiple alcohol-related sensory cues to make drinking decisions. Recently, our lab has developed a paradigm for studying how drinking decisions are influenced by visual alcohol-related cues. Here, we extended

that paradigm to the multisensory realm by pairing visual alcohol cues with party music (i.e., music highly associated with heavy-drinking environments). Subjects were all young adult women, separated into heavyand light-drinking cohorts. Subjects were asked to list their favorite songs for 'going out' (henceforth, party music) and 'staying in' (home music), which were then played as song clips during the task. For the task, participants were asked to imagine themselves in one of several risky scenarios while music played in the background. They were shown visual alcohol and food cues and were asked to report their likelihood of drinking or eating the pictured item. We found that listening to party music increased the likelihood of a risky decision (over home music or no music) significantly more for alcohol cues than food. Party music did not influence heavy and light drinkers differently, even though heavy drinkers were much more likely than light drinkers to endorse alcohol over food decisions. The results show that auditory and visual alcohol-related cues interact to influence decisions. The results highlight the importance of considering domain-specific sensory experience and associations when studying decision-making in context.

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P2.46 Differential effects of music and pictures on taste perception – an fMRI study

Callan, A., Callan, D. & Ando, H. National Institute of Information and Communications Technology

Similarly to other sensory modalities, gustatory perception is multimodal in nature. It is easy to imagine that the looks and smells of food as well as the sounds of cooking/eating influence our gustatory perception. However, it is hard to believe that sounds that are not directly related to food can affect how we taste. Crisinel et al. (2012) demonstrated that the pitch of background music affects taste perception. People tasted a piece of toffee sweeter with higher-pitched background music and bitterer with lowerpitched background music. In this fMRI study, we investigated how indirectauditory-taste cues and direct-visual-taste cues modulate neural activity in the primary gustatory cortex without taste stimuli. The high-pitched music and dessert pictures were used to reflect sweet taste and the low-pitched music and meal pictures were used to reflect non-sweet taste. Stimuli were presented in auditory-only, visual-only, or audio-visual conditions. Results from the auditory-only condition indicated that the sweet music enhanced activity in the posterior insula (plns) than the non-sweet music. In the visualonly conditions, no significant differences were found. Paired comparisons of the audio-visual conditions showed significant differences. The sweetmusic and dessert-picture condition activated the right plns more than the sweet-music and meal-picture condition. In contrast, the non-sweet-music

and meal-picture condition activated the left anterior Insula (alns) more than the sweet-music and meal-picture condition. Regions of interest analyses revealed different patterns of activity in the right plns and left alns. The right plns was activated by the sweet music but not by the non-sweet music. These results suggest that enhanced activity in the plns was caused by the sweet music and that presentation of non-sweet meal pictures suppressed the activity. On the other hand, both types of food pictures activated the left alns and the activity was enhanced by simultaneous presentation of gustatory congruent music.

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P2.47 Comparing the effects of vision and smell in red wine quality judgments by experts: constrained tasting vs. unconstrained tasting Caissie, A., De Revel, G. & Tempère, S.

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In this study, we evaluated the contributions of vision and smell to red wine quality judgments by expert wine tasters. We compared responses in two unconstrained (i.e., global) and two constrained (i.e., vision only and smell only) wine tastings. In each tastings, 47 wine tasters (18 women) were instructed to rate 20 red wines successively according to five continuous response scales: Arousal, Quality, Certainty, Image and Hedonism. Arousal was defined as the strength of the sensory response (lower vs. higher) to the wine being tasted. Quality was defined as the degree of exemplarity or liking of the wine being tasted, to a pre-conditioned quality standard (poor example vs. good example of quality). Ratings about the wine's potential to evoke images (low image vs. high image) and hedonism (dislike vs. like) were collated. Wine tasters also rated the certainty of their quality ratings. A priori designations of quality served as the criteria for the red wines. Each wine belonged to the same sensory space (i.e., secondary wines vs. premium wines) from a Protected Designation of Origin (PDO) for which the wine tasters had prior experience. Overall, our results suggest a coherent quality concept across unconstrained and constrained wine tastings, with a clear distinction favoring premium wines on all scales. However, we observed modality specific effects in arousal and evoked images, as well as certainty. Wine tasters were less certain about their quality judgments in constrained tastings compared to unconstrained (global) tastings. They also reported less arousal and less evoked images with vision compared to smell. Repeatability in ratings, from unconstrained to constrained (Global-Visual, Global-Smell) tastings, suggested more stability across modalities for arousal, quality and evoked images of premium wines, compared to

secondary wines. Visual judgments were better associated to global judgments (Global-Visual) when compared to smell (Global-Smell).

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P2.48 Acute pain does not disrupt updating of peripersonal space and body representation

Halicka, M., Proulx, M.J., Wilson, M., Buckingham, G. & Bultitude, J. University of Bath, UK; University of Exeter, UK

The multisensory representations of our body and its surrounding space are constantly updated as we interact with objects in our environment, for instance during active tool-use. People with chronic pain conditions can present with distorted representations of their body and peripersonal space when compared to pain-free individuals. It has been suggested that disruption to the processes involved in updating these representations could underlie some of these painful conditions. However, it is not known why such updating problems might occur: for example, if they reflect a difference in cognitive processing that pre-date the development of pain, or if they are a consequence of pain. To test the latter, we induced acute pain in healthy individuals using 1% Capsaicin cream and examined its effect on participants' abilities to update the representation of their body and peripersonal space during tool-use. Updating of the body representation was examined by comparing tactile distance judgements on participant's arms before and after tool-use. Updating of peripersonal space representation was examined during active tool-use by measuring changes in reaction times and error rates for decisions made about vibro-tactile stimuli presented through the handles of the tools in the presence of visual distractors at the tips of the tools. Acute pain did not alter performance on either task when compared to active placebo cream and a neutral control condition. This suggests that acute pain is not sufficient to account for the distorted representations of the body and its surrounding space observed in people with painful conditions.

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P2.49 Visual Assessment of Tactile Roughness Intensity

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A number of neuroimaging studies have consistently reported significant activations in human somatosensory cortices during observation of touch actions. However, it is still debated which brain region is mainly associated with the processing of observed touch (e.g. primary somatosensory cortex; S1, secondary somatosensory cortex; S2, posterior parietal cortex; PPC). In this fMRI study, we searched for brain regions exhibiting neural activity patterns encoding visually evoked roughness intensities. Fifteen healthy volunteers with no deficits in tactile and visual processing participated. They first explored a set of differently colored sandpapers with their right index fingertip outside of the MR room. During the fMRI experiment, video clips of tactile explorations of the sandpaper set were presented and the participants were asked to recall the perceived roughness intensity as vividly as possible. The neural representations of the roughness intensities could be successfully decoded from the brain signals elicited by the video clips in the absence of any intrinsic tactile content. In particular, a randomeffects group analysis revealed that four brain regions encoded the different roughness intensities distinctively: The bilateral PPC, the primary visual cortex (V1), and the ipsilateral S1. Although we found brain activations in ipsilateral S1, we cannot confirm the S1 engagement because the majority of previous studies have reported brain activations in contralateral S1. Significant decoding accuracies in V1 may be attributed to differences of visual contents in the presented video clips. Therefore, among the three brain regions mentioned above, our findings supported the hypothesis that especially the PPC plays an important role in the processing of observed touch.

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P2.50 Predicting the endpoint of an ongoing reaching movement: You need more than vision but do you really need to plan the action?

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The motor commands generated prior to voluntary actions are deemed important for the control of voluntary movements (Wolpert & Ghahramani, 2000). According to the multiple processes of online control model (Elliott et al., 2010), the earliest phase of an ongoing movement (i.e., impulse regulation) indeed relies on the efferent commands while the following

phase (i.e., limb-target regulation) only requires vision and proprioception. The purpose of this study was to provide original empirical evidence regarding the importance of visual and proprioceptive feedback availability vs. the efferent command to make endpoint error predictions (i.e., limbtarget regulation). Visual information was limited to a brief window of vision (40 ms) early in the trajectory, as it has been shown that vision provided early in the movement could be utilized in making accurate endpoint error judgements while also allowing for the assessment of online feedback utilization. In the experimental conditions, participants: a) reached actively to a target (efference + vision + proprioception: EVP); b) were guided to the target using a robotic arm (vision + proprioception: VP); and c) observed a fake hand guided to a target (vision only: V). The limb trajectories from the active condition (EVP) were used to program the robot for the two other experimental conditions (VP, V), so the trajectories in the robot-guided conditions were those of the participant themselves. After each trial, participants reported if the hand undershot or overshot the target and the accuracy of these judgements was analysed. Participants' endpoint error predictions were better in active (EVP) compared to both robot-guided conditions (VP & V) and better with both vision and proprioception (VP) than with vision alone (V). Thus, online limb-target regulation processes may not only rely on vision and proprioception but also on the efferent command.

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P2.51 The duration aftereffect occurs in tactile modality

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Adaptation to a relatively short or long stimulus leads to a robust repulsive duration aftereffect. This illusory temporal perception has been shown in visual and auditory modalities, which is hardly transferrable between the two modalities. Here, we investigated whether the duration aftereffect could be realized in the tactile modality. We implemented two experiments. In Experiment 1, we used perceptual estimation in which participants compared the duration of individual test stimulus with reference to the mean duration of a group of test stimuli (the method of single stimuli). In Experiment 2, we adopted temporal reproduction paradigm in which participants pressed and released a button to generate the duration to be equivalent to the duration of test stimulus as accurately as possible.

We replicated the repulsive effect as in auditory/visual modalities: adaptation to a relatively short vibrotactile stimulus resulted in perceiving long duration for the subsequent vibrotactile stimulus, and vice versa for the adaptation to long stimulus (Exp.1). Moreover, reproduced duration was significantly longer after adaptation to relatively short vibrotactile stimulus than the one after long stimulus (Exp.2). These findings indicate an abstract time representations across different sensory modalities.

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P2.52 Haptic-visual interactions for stiffness perception in the human cerebral cortex studied with an fMRI-compatible pinch device

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Haptic-visual interactions for the perception of object properties such as size, shape, and stiffness have been extensively studied in behavioral experiments applying virtual reality systems. However, the study of these interactions with fMRI is severely limited by the fact that most of conventional electromagnetic devices are disturbed by the magnetic field and affect the imaging quality. To overcome this problem, we developed an fMRI-compatible device using an ultrasonic motor and optical sensors to simulate the sensation of pinching objects. This study investigated neural substrates of multimodal stiffness perception utilizing the pinch device. Although stiffness perception intrinsically relies on haptic information, stiffness is inherently an integrated property of displacement and force. Psychophysical literatures have reported that perceived multimodal estimate of stiffness is consistently influenced by visual feedback and suggested that each modality combines cues to arrive at an estimate of stiffness and then these estimates are integrated into a multimodal value. In our experiments, participants pinched virtual objects of different stiffness levels and received visual feedbacks either congruent with or faster/slower than their finger movements. By examining cortical regions that were more activated by haptic-visual information compared with unimodal conditions in a one-back stiffness comparison task, we could identify regions in inferior parietal lobule including supramarginal gyrus and angular gyrus that were different from the regions (contralateral postcentral gyrus, bilateral parietal operculum, visual cortex) reported in previous researches for haptic-only stiffness perception and visual tasks, which may be candidates for hapticvisual interaction in stiffness perception.

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P2.53 Apparent increase in lips size improves tactile discrimination

Ambron E.A., Medina J.M., Coyle M.C. & Coslett, H.B.C. University of Pennsylvania

Magnifying the vision of one's body part improves tactile acuity. We explored the effect on tactile acuity of an apparent increase in size of a body part induced by an anesthetic cream. Application of an anaesthetic cream (benzocaine) to the lips caused many subjects to perceive their lips as larger, while this enlargement was not perceived with the application of simple moisturizing cream. Tactile discrimination as judged by two-point discrimination improved as function of the degree of increase in perceived lips size with the anesthetic cream, while this effect was not observed with moisturizing cream. These data demonstrate that a subjectively experienced increase in the body part size enhances tactile discrimination of the body part. These data are consistent with the hypothesis that magnification effects are mediated by a malleable, experience dependent representation.

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P2.54 Differential Importance of Visual and Haptic Information in Postural Control among Different Standing Postures

Cheung, T.C.K., Bhati, P., Jenish, C. & Schmuckler, M.A. Department of Psychology, University of Toronto Scarborough

Maintaining balance requires multisensory inputs. Previous work has demonstrated fundamental roles for both visual and haptic inputs in postural control, with increased postural stability in lit versus dark environments, and increased postural stability when observers receive light fingertip contact information, even when this contact is not weight supporting. Interestingly, little work has examined the role of such visual and haptic inputs in standing postures varying in the length and width of the base of support. A pair of experiments examined adults' postural stability under conditions systematically combining the presence versus absence of visual input, the presence versus absence of haptic input, and four different standing postures – natural standing posture (feet shoulder width apart), feet

together, tandem stance (toe of the back foot touching the heel of the front foot), and Chaplin stance (heels together, feet approximately 90 degree angle). These experiments were distinguished by the type of haptic input provided, with Experiment 1 providing stable light fingertip support, and Experiment 2 providing unstable light fingertip support. Under conditions of stable haptic input, measures of postural stability demonstrated that when the stances became increasingly unstable (e.g., decreased based of support), visual and haptic inputs became increasing salient, as indicated by interaction effects. When haptic input became unstable, however, the benefits typically observed for haptic inputs disappeared, although the benefit of visual input was retained. Thus, although both visual and stable haptic information increasingly facilitated stability in standing postures ranging from stable to unstable, with unstable haptic information the visual input dominated the regulation of stance across standing postures. These results potentially inform rehabilitation and risk prevention for people with high fall risk and motor disorders.

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P2.55 Multisensory benefits and multisensory interactions are not equivalent: A comparative, model-based approach Innes, B.R. & Otto, T. U.

University of St. Andrews

Multisensory signals allow for faster response times (RTs) than the unisensory components. While this redundant signals effect (RSE) has been widely studied with diverse signals, no modelling framework has explored the RSE across studies systematically. To enable a comparative approach, here, we propose three steps: The first quantifies the size of the RSE compared to parameter-free race model predictions. The second quantifies processing interactions beyond the race mechanism: history effects and so-called violations of Miller's bound. The third models the RSE on the level of RT distributions by adding two free model parameters: a correlation parameter covers history effects; additional noise in multisensory conditions accounts for violations off Miller's bound. Mimicking the diversity of studies in a 2x2 design, we then tested different audio-visual signals that target the two processing interactions. The first factor Stimulus Construction had levels 'simple' (i.e. non-random, with strong transient signal onsets) and 'complex' (i.e. randomly-generated, with weak transient signal onsets). The second factor Signal Features had levels 'consistent' (i.e. only one signal variant per modality) and 'alternating' (i.e. two signal variants per modality). We show that the parameter-free race model provides overall a strong predictor of the RSE across factors. Regarding the additional interactions, we found that history effects, and the associated correlation parameter, do not depend on the repetition of low-level signal features. Furthermore,

larger violations of Miller's bound, and consequently the associated additional noise, seem to be linked to transient signal onsets. Critically, this latter parameter dissociates from the size of the RSE, which demonstrates that multisensory interactions and multisensory benefits are not equivalent. Overall, we argue that our approach, as a blueprint, provides both a general framework and the precision needed to understand the RSE across sensory modalities and participant groups.

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P2.56 Leveraging multisensory neurons and circuits in assessing theories of consciousness

Noel, J.P., Ishizawa, Y., Patel, S.R., Brown, E.N., Eskandar, E.N. & Wallace, M.T. Vanderbilt University

Detailing the neural mechanisms enabling wakefulness and conscious experience is a central and unanswered question in systems neuroscience despite its paramount clinical implications in a host of disorders of consciousness. Predicated on two of the frontrunner theories of consciousness, the information integration theory (IIT) and global neuronal workspace (GNW) theory, we generate a number of concrete neurophysiological predictions and test these predictions with a neuronal dataset collected from macaques. According to the IIT and its "consciousness-meter" (phi, Î;), in transitions between conscious and unconscious states, neurons that actively integrate information (AND gates), as opposed to those that simply converge information (XOR gates), should be most readily impacted. Conversely, when an organism is aware, neurons that integrate should exhibit properties of consciousness to a greater degree than neurons that converge information. We tested these predictions by recording single unit activity in primary somatosensory (S1) and ventral pre-motor (vPM) areas in non-human primates that are administered audio-tactile (AT), tactile (T), and audio (A) stimuli and in which states of consciousness are modulated via propofol anesthesia. Responding to either A or T stimulation was considered to represent an XOR gate, while being activated to a greater extent by the co-occurrence of A and T (i.e., AT) stimulation than to each stimulus alone (i.e., multisensory enhancement) was considered to represent an AND gate. Contrary to the IIT prediction, when animals are rendered unconscious a greater degree to convergent neurons (XOR gates) stop converging than integrative neurons (AND gates) stop integrating. Furthermore, measures of neural complexity and noise correlations more faithfully track the animals' consciousness state for convergent neurons when compared with integrative neurons. On the other hand, according to the GNW theory, conscious percepts should result

in sustained neural activity and in greater single trial co-activation of S1 and vPM than under unconscious conditions. Both of these predictions are supported in the neurophysiological data. Collectively, these results provide more empirical support for the GNW, as compared with the IIT, theory of consciousness.

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P2.57 A simple law that governs most multisensory amplifications and enhancements

Billock, V.A. & Havig, P.R. College of Optometry, Ohio State University

Under a vast variety of conditions, the presence of one sensory signal can enhance or amplify another (Stanford & Stein, 2007). Usually weak signals are amplified more than strong (the Principle of Inverse Effectiveness), but there has been little attempt (to our knowledge) to guantify the lawful nature of the amplification. We find that (with one important exception) the amplified response is a power law of the unamplified response, with a compressive exponent that accounts for the general finding of inverse effectiveness; i.e., AmplifiedResponse = a*UnamplifiedResponse^n. This simple power law amplification accounts for both human psychophysical data and animal electrophysiology. It accounts for spike rate data in cortical subthreshold multisensory cells, and mass action cortical current source densities and multiunit activity. It accounts for both amplification between senses (visual modulated by auditory, auditory modulated by tactile) and amplification within a sense (in this case human color vision). The r^2 values for these power law fits are so high that these enhancements can all be considered gated-amplifications rather than nonlinear combinations. The sole but important exception is for overtly multi-modal neurons, especially in superior colliculus. The spike rate enhancements in animals and the psychophysical enhancements in humans have slightly compressive exponents (circa 0.85). Some other enhancements show greater compression (more inverse effectiveness). The similarity of psychophysical enhancement and spike rate enhancement in anesthetized animals argue against attention having a role in psychophysical multisensory enhancement. A neural model grounded in sensory binding theory closely approximates the power law behavior seen psychophysically and electrophysiologically.

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P2.58 A perspective on two potential mechanisms underlying different modes of multisensory integration

Nidiffer, A.R., Ramachandran, R. & Wallace, M.T. Vanderbilt University

The integration of signals across modalities has been previously described based on their spatial and temporal proximity. In short, unisensory signals that occur in close spatial and temporal proximity tend to produce response enhancements whereas stimuli falling outside a spatial or temporal window are not integrated or result in response depressions. Spatial and temporal proximity has been demonstrated to be an important factor in multisensory responses as measured in behavior, electrophysiology, and imaging. However, under certain conditions, these principles fail to account for multisensory interactions. Recent behavioral findings have related some multisensory behaviors to another feature, one based on the similarity of the temporal structure between unisensory cues. This cue, temporal correlation, serves as a strong predictor of whether two unisensory cues (for example, mouth movements and vocal intensity) originate from a common source (a speaker), i.e., multisensory binding. Binding has been shown to be somewhat resistant to spatial and temporal disparities. Here, we hypothesize that multisensory interactions occur dependent on at least two separate mechanisms: one based on the proximity of sensory cues in the environment and another based on the similarity in temporal structure. We present a reanalysis of data from a recent experiment suggesting that these two modes can be measurably dissociated. Further, we hypothesize a potential developmental link between the mechanisms. We go on to propose a set of experiments to test these hypotheses.

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P2.59 An analysis and modelling toolbox to study multisensory response times

Otto, T.U. University of St Andrews

Responses to redundant signals from different sensory modalities are typically faster than responses to the uni-sensory components. This redundant signals effect (RSE) has been extensively studied not only with an impressive variety of signals, covering all five classic senses, but also with different subject populations focusing on development, aging, and clinical samples. Remarkably, despite intensive research, a standardized

methodology to systematically analyse and interpret the RSE is still not consistently developed. Moreover, the most obvious modelling approach to explain the effect, the so-called race model championed by Raab (1962), is typically not fully appreciated in its explanatory power. To facilitate a comparative approach across studies, here, we present a toolbox, implemented in MATLAB, which includes a wide range of functions that allow (1) to simulate the RSE, (2) to perform standardized operations of basic RT analysis, (3) to precisely measure and analyse the RSE on the level of response time distributions, and (4) to fit the most recent race model, as proposed by Otto and Mamassian (2012), using maximum likelihood estimation. The presentation of the model functions is accompanied by parameter recovery simulations to validate the fitting procedures. One critical finding is that parameter recovery with reaction time distributions averaged across subjects can be biased, which consequently should be avoided when studying the RSE. The use of the toolbox is illustrated by example code and all functions are supported by help-documentation.

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P2.60 A neurocomputational model of synapse maturation explains Bayesian estimate and causal inference in a multisensory environment

Cuppini, C., Magosso, E. & Ursino, M. University of Bologna

Experimental and theoretical studies suggest that the brain integrates information from different sensory modalities following Bayesian rules, to generate an accurate percept of external events. Despite the empirical evidence, neural mechanisms responsible for this behavior are still insufficiently understood. The aim of this work is to summarize the main aspects of a neurocomputational model realized recently, based on physiologically plausible hypotheses. The model produces estimates of external events in agreement with Bayesian rules, and suggests architectural and neuronal mechanisms responsible for such abilities. Additionally, it can be used to investigate how a multisensory environment can affect the maturation of multisensory integrative abilities.

The model presents a hierarchical structure: two unisensory layers (auditory and visual) receive the corresponding sensory input through plastic receptive field synapses. These regions are topologically organized and reciprocally connected via excitatory synapses, which encode the spatial and temporal co-occurrence of visual-auditory inputs. Based on sensory experience, synapses are trained, by means of Hebbian learning rules. Finally, these unisensory regions send excitatory connections to a third multisensory layer, responsible for the solution of the causal inference problem.

Simulations show that, after a multisensory training, the receptive fields shrink to reproduce the accuracy of perceived inputs, realizing the likelihood estimate of unisensory spatial position. Moreover, information on prior probability of the co-occurrence of audio-visual stimuli is encoded in the cross-modal synapses, realizing a Bayesian estimate in multisensory conditions. This model has been tested in a variety of stimulus conditions comparing its results with behavioral data reported in the literature. Among others, the network can account for the ventriloquism illusion, the effect of the audio-visual spatial disparity on the percept of unity, the dependence of the auditory error on the causal inference. Finally, model results suggest that the probability matching is the perceptual strategy used in auditoryvisual spatial localization tasks.

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P2.61 Dynamic decoding of unisensory and multisensory stimulus processing in conscious and unconscious primate cortex

Tovar, D.A., Noel, J.P., Ishizawa, Y., Patel, S.R., Brown, E.N., Eskandar, E.N. & Wallace, M.T.

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While awake, given a sufficiently salient stimulus, we are seamlessly able to identify the presence and characteristics of a stimulus. However, in an unconscious state, we are no longer able to identify the presence nor the characteristics of the formerly salient stimulus. Although this process takes place every night when we go to sleep, much is unknown about how the

brain processes stimuli in lower and higher order cortical areas across conscious states. In this study, we used time-resolved neural decoding to analyze neural activity collected with an electrode microarray in primary somatosensory (S1) and ventral premotor (vPM) areas. Primates were presented with auditory, tactile, and audiotactile stimuli while awake and unconscious. The primary goals of the analysis were to find decoding differences across states of consciousness for 1) the presence or absence of stimuli and 2) differentiating the modality of the stimulus (auditory, tactile, and audiotactile). In general, our results show above chance decoding for both conscious and unconscious states. However, the conscious state showed higher decoding for both stimulus detection and modality in both S1 and vPM, as well as longer, sustained, above chance decoding as compared to the unconscious state. This finding agrees with previous work that shows longer sustained neural activity for conscious percepts. Interestingly, the decoding difference between conscious and unconscious states was significantly greater (Wilcoxon signed-rank test, p < 0.001) for stimulus detection than it was for modality in both S1 and vPM. This finding suggests that conscious awareness confers the greatest advantage for detecting the presence of stimuli in the brain, while secondarily enhancing our ability to the detect the characteristics of the stimuli. Further analysis will use generalization decoding techniques to investigate common neural substrates across time and conscious states.

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P2.62 Therapeutic applications: Dance in the treatment of neurodegenerative and chronic disorders Barnstaple, R., Fontenasi, C. & DeSouza, J.

York University

Dance, an intensively multimodal activity, engages both top-down and bottom-up brain processes (Bar & DeSouza, 2016), providing a rich source of material for researchers interested in the integration of movement and cognition (BIŤsing et al, 2012). Simultaneously involving memory, visualspatial awareness, kinesthetic and vestibular information, motor imagery, touch, imagination, timing, sound and musical/social elements, dance practices challenge the central nervous system (CNS) in novel and stimulating ways (Dhami, Calvo-Moreno & DeSouza, 2015). Fostering integration of multisensory stimuli and coordinating both inter/intra personal responses, movement to music nurtures plasticity, stimulates development, and promotes neurorehabilitation across the lifespan. Dance interventions for neurodegenerative conditions such as Parkinson's disease (PD) and Alzheimer's disease (AD), as well as other conditions including multiple sclerosis (MS), chronic pain (CP), and mental health, have been the subject of numerous studies over the last decade, with observed benefits ranging from physical (balance, gait, diminution of motor symptoms) to cognitive (improved performance on memory and concentration tasks) and emotional improvements (mood scores and self-efficacy. Multisensory integration provides a useful framework through which to understand the effects of dance while offering theoretical models that may explain the mechanisms by which improvements are accomplished. We present initial data with two different populations participating in dance therapy – PD and CP – that demonstrates both how the benefits of dance therapy may be related to improvements in multisensory integration, while modelling how tools related to multisensory integration may be well-adapted to measure the effects of dance interventions.

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P2.63 Visual and auditory cueing of learnt dance choreography in expert dancers and people with Parkinson's disease (PD).

DeSouza, J.F.X. Centre for Vision Research

At IMRF 2013, we presented analysis on our project examining the neural networks involved in learning a new ballet to a novel piece of music over 8 months with a focus on auditory cortex (DeSouza & Bar 2012; DOI: 10.1163/187847612X646677). We scanned subjects (expert dancers and people with PD) up to four times using fMRI. To date, we have now scanned 18 professional dancers from the National Ballet of Canada, 12 controls and 10 people with PD. All subjects visualized dancing to a oneminute piece of music during an 8-minute fMRI scan. Subjects were asked to visualize dancing their part while listening to their specific music. For more details of the training and performances for the first of 4 cohorts (Bar & DeSouza, 2016) DOI: 10.1371/journal.pone.0147731. Preliminary results revealed a significant increase of BOLD signal, across the sessions in a network of brain regions including bilateral auditory cortex and supplementary motor cortex (SMA) over the first three imaging sessions, but a reduction in the fourth session at 8-months. This reduction in activity was not observed in basal ganglia. Does this learning curve with increase and decrease in BOLD signal when cued by auditory or visual and auditory stimuli? Our results suggest that as we learn a complex motor sequence in time to music, neuronal activity increases until performance and then decreases by 34-weeks, possibly a result of overlearning and habit formation. Our findings may also highlight the unique role of basal ganglia regions in the learning of motor sequences. We now aim to use these functional regions of activation as seed regions to explore structural (DTI) and functional connectivity analysis.

Acknowledgments: NSERC Discovery grant

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P2.64 A new approach to compare the quality of allocentric and egocentric spatial navigation

Bock, O. & Fricke, M. German sport University

Navigation through buildings and towns can rely on an egocentric or on an allocentric representation (i.e., associating viewed landmarks with changes of direction, versus using a topographically organized "mental map"). These two representations are thought to reside in different brain areas, and to be differently vulnerable by aging. Available tests of spatial navigation either don't discriminate between the two representations, or they assess only the preference for one of the two representations, or they assess the quality only of allocentric navigation. No tests are available yet to assess the quality of egocentric navigation.

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P2.65 The Influence of Dance for Young Adults with Disabilities

Andrew, R.-A., Reinders, N.J., & DeSouza, J.F.X. York University

The benefits of dance have become a popular subject of research worldwide as unlikely demographics, such as people with Parkinson's disease, are dancing to improve their health. Dance is a multisensory activity that incorporates physical exercise, creativity, and spatial-temporal skills; these components are ideal for improving neural connectivity and enhance brain plasticity. Regular participation in dance classes has been shown to have a positive effect on participants' mental health. Our study examined putative benefits on 8 disabled young adults, 3 males and 5 females, median age of 22.5 yrs.), who participated in 10 1-hour dance classes over 5 weeks in a dance class developed specifically for people with disabilities. Although there are some community dance classes that are inclusive of disabled people, this class combined features of community dance with the sequential, skills-based classes available to able-bodied youth. We used interviews, videos, and guestionnaires to assess participants' mood. In addition, we used electro-encephalography (EEG) to examine individual participants' changes in resting state (rsEEG) before and after a dance class. Asymmetry in alpha band frequency (8-13Hz) has been associated with negative affect and increased wave function in any single frequency band can improve functional connectivity across all networks (Gordon, Palmer & Cooper, 2010; Cruz-Garza et al., 2014). We used the Emotiv Epoch wireless headset which is a quick, non-invasive method of neuroimaging that is also portable. The dance classes were designed and implemented following the principles of disability rights models; medical diagnoses were not disclosed. In this study, 'disabled' may refer to physical, developmental, cognitive, or mental health impairments. We expect the results of this study will contribute to the existing research into the benefits of dance and provide a clear understanding of the impact dance may have on the lives of disabled people.

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P2.66 Distance perception of an object that moves with you

Kim, J. J. & Harris, H. R. York University

The perceived distance to objects in the environment needs to be updated during self-motion. Such updating needs to be overridden if the object moves with the observer (such as when reading a phone while walking). Errors in updating could lead to errors in perceived distance and, because of size/distance invariance, to errors in perceived size. To look for such errors, we measured the perceived size of an object that moved with the observer during visually simulated self-motion.

Participants judged whether a vertical rod presented on the ground plane in a virtual-reality-simulated scene at fixed distances of 2-10m, appeared longer or shorter than a physical reference rod (45cm) that they held in their hands either vertically or horizontally. Observers were either stationary or in the presence of optic flow compatible with moving at 1m/s or 10m/s forwards or backwards. Viewing was either monoscopic or stereoscopic. The length of the visual rod was varied by an adaptive staircase and responses were fitted with a logistic function to determine the PSE.

The rod generally needed to be longer than the physical rod to be judged as equal to its size. Errors were smaller when viewing monoscopically compared to stereoscopically (+16%). The orientation of the reference rod influenced size judgements, with larger errors when the rod was held horizontally (+16%) compare to when it was held vertically (+6%). However, there were no significant differences observed in the errors in perceived rod size due to optic flow.

We interpret the errors in the perceived size as resulting from an error in perceived distance. Thus, we confirm the well-known observation that perceived distances are compressed in a virtual environment. However, this compression effect disappeared with monoscopic viewing. Our ability to update the distance of an object moving with us appears robust during forward and backward self-motion.

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P2.67 The sound of us walking together in time and space: Exploring how temporal coupling affects represented body size, peripersonal and interpersonal space in group interactions

Fairhurst M.F.*, Tajadura-Jiménez, A.*, Keller, P.E. & Deroy, O. * Shared 1st authorship Universidad Carlos III de Madrid & University College London

Coordinating our actions in time and space with others has been suggested to act as a social glue, holding interacting groups together. Whether as part of a marching band or simply walking down a sidewalk, we regularly hear and integrate the sounds and proprioceptive information of our footsteps along with those sounds of others. This often leads to a sense of being part of a group and of personal enlargement. In this study, participants marched in synchrony with the sound of a metronome, while listening to footstep sounds of 8 confederates walking around them. In a 2x2 factorial design, we manipulated the footstep sounds of the group, varying temporal synchronicity (synchronous or asynchronous with the metronome) and congruency (same versus different footwear to the participant). This changed how similar in timing and quality the participant footsteps were relative to the others. We measured temporal coordination and subsequent changes in feelings about self and others, represented body size, peripersonal space and comfort interpersonal distance. Beyond merely tracking interpersonal affiliation, our results show a main effect of synchronicity on peripersonal space, with larger distances in the asynchronous conditions, while for interpersonal distance an interaction between synchronicity and congruency is observed, with the smallest distance in the same footwear, synchronous condition. Synchronicity with the group had positive effects in reports of body strength and elongation, emotional valence and dominance, and feelings of affiliation. We will discuss these results and their correlations with gait changes related to sensorimotor synchronization and represented body weight. We suggest that when part of a larger group, we feel a smaller part of the whole thus affecting our action space accordingly. Further, the more similar we sound as a group, the closer we feel to others.

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P2.68 Is Attentional Resource Allocation Across Sensory Modalities Task-Dependent?

Wahn, B. & König, P. University of British Columbia

Human information processing is limited by attentional resources. That is, via attentional mechanisms, humans select only a part of the sensory input for further processing at the expense of neglecting other sensory input. In multisensory research, a matter of ongoing debate is whether there are distinct pools of attentional resources for the sensory modalities or whether attentional resources are shared across the sensory modalities. Recent studies have suggested that attentional resource allocation across the sensory modalities is in part task-dependent. That is, the recruitment of attentional resources across the sensory modalities depends on whether processing involves feature-based attention (e.g., the discrimination of stimulus attributes) or spatial attention (e.g., the localization of stimuli). Here, we present a line of experiments (Wahn & König, 2015a,b; Wahn, Schwandt, Krüger, Crafa, Nunnendorf, & König, 2015; Wahn & König, 2016; Wahn, Murali, Sinnett, & König, 2017) and a review of the literature (Wahn & König, 2017) supporting this view. For the visual and auditory sensory modalities, findings suggest that distinct resources are recruited when humans perform feature-based attention tasks, whereas for the visual and tactile sensory modalities, partly shared resources are recruited. If featurebased attention tasks are time-critical, shared resources are recruited across the sensory modalities. When humans perform a feature-based attention task in combination with a spatial attention task, partly shared resources are recruited across the sensory modalities as well. Conversely, for spatial attention tasks, attentional processing does consistently involve shared attentional resources for the sensory modalities. Overall, these findings suggest that the attentional system flexibly allocates attentional resources depending on task demands (i.e., whether spatial and/or featurebased attention is required) and the involved sensory modalities. 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.

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P2.69 Visual-Inertial interactions in the perception of translational motion de Winkel, K.N. & Bülthoff, H.H. Max Planck Institute for Biological Cybernetics

Recent work indicates that the central nervous system forms multisensory perceptions differently depending on inferred signal causality. In accordance with these findings, we hypothesize that multisensory perception of traveled distance in the horizontal plane conforms to such Causal Inference (CI).

Participants (n=13) were seated in the Max Planck Cablerobot Simulator, and shown a photo-realistic rendering of the simulator hall via a Head-Mounted Display. Using this setup, they were presented various unisensory and (incongruent) multisensory visual-inertial horizontal linear surge motions, differing only in amplitude (i.e., distance). Participants performed both a Magnitude Estimation and a Two-Interval Forced Choice task. We modeled the responses in the tasks according to a CI model, as well as competing models (Cue Capture, Forced Fusion), and compared the models based on their fits.

The data indicate that distance is somewhat underestimated for both the visual and inertial unisensory channels, and that differential thresholds increase with physical distance -in accordance with a Weber's law. Preliminary findings on model comparisons favor different models in different individuals, with an overall preference for the CI model. However, the data also suggest that different priors may be needed to account for differences between the tasks.

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P2.70 Listening to a conversation with aggressive content expands the interpersonal space

Vagnoni, E., Lewis, J., Tajadura-Jiménez, A. & Cardini, F. Anglia Ruskin University

The distance individuals maintain between themselves and others can be defined as 'interpersonal space'. This distance can be modulated both by situational factors and individual characteristics. Here we investigated the influence that the interpretation of other people interaction, in which one is not directly involved, may have on a person's interpersonal space. In the current study we measured, for the first time, whether the size of interpersonal space changes after listening to other people conversations with neutral or aggressive content. The results showed that the interpersonal space expands after listening to a conversation with aggressive content relative to a conversation with a neutral content. This finding suggests that participants tend to distance themselves from an aggressive confrontation even if they are not involved in it. These results are in line with the view of the interpersonal space as a safety zone surrounding one's body.

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P2.71 Social modulation of audiotactile integration near the body

Hobeika L., Taffou M. & Viaud-Delmon, I. IRCAM, Sorbonne Université, Laboratoire STMS

Peri-personal space (PPS), the space immediately surrounding our bodies, rules the multisensory integration boost of stimuli. As a space of interaction with the external world, PPS is involved in the control of motor action as well as in the protection of the body. Its boundaries are flexible but little is known about their modulation by the presence or interaction with other individuals. We investigated whether PPS boundaries are modulated in the presence of an inactive individual, and when participants are performing a task in collaboration or in competition with a partner. We used a modified version of Canzoneri et al. (2012) audiotactile interaction task in three groups of right-handed participants. In each group, participants performed the task both in isolation and with another participant, inactive (audience group) or doing the task as well in collaboration (collaborative group) or in competition (competitive group). They had to detect as fast as possible a tactile stimulus administered on their hand, while task-irrelevant sounds were presented, looming from the right and left participants front hemifields. The sound stimuli were processed through binaural rendering. Tactile stimuli were processed when the sound was perceived at varying distances from participant's body. Mean reaction times to the tactile stimuli at the different perceived sound distances were compared and used to estimate PPS boundaries. PPS boundaries were modulated only when participants acted in collaboration with a partner, in the form of an extension on the right hemispace, and independently of the location of the partner. This suggests

that space processing is modified during tasks performed in collaboration, and questions the notion of motor space during group actions.

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P2.72 Modulation of Self-recognition by Interpersonal Synchronization Hao, Q., Ora, H., Ogawa, K., Amano, S. & Miyake, Y. School of Computing, Tokyo Institute of Technology

Self-recognition including sense of agency and ownership still remains a big mystery, which attracts many interests of psychological researchers using rubber hand illusion to investigate the self-recognition. However, few studies have investigated the self-recognition during interpersonal interaction such as face to face interaction in our daily life. Such face to face interaction includes two types of movements, mirror or non-mirror symmetric movements. For example, previous studies investigated the synchronous movement of a human's hand and a rubber hand, which were arranged to face each other. These studies reported weak sense of agency, but not ownership, when the participants viewed the movement of a right or left rubber hand that was synchronized with their right hands' movement. Although one previous study reported that both of sense of agency and ownership were elicited in interpersonal synchronization, it focused on the condition of mirror symmetry movements only. That is, the participants' right or left hand fist-clenching movement was synchronously imitated by a faceto-face sat experimenter's left or right hand movement, respectively. Hence, the present study designed two conditions corresponding to mirror and nonmirror symmetry movements, thereby investigating the self-recognition (sense of agency and ownership) in interpersonal synchronization. In the mirror symmetry condition, the participants moved their right or left hand and saw the synchronous movement of a face-to-face sat experimenter's left or right hand, respectively, while the non-mirror symmetry condition made the experimenter's right or left hand synchronized with the participants' right or left hand, respectively. The results showed that sense of agency and ownership were significantly elicited in both the mirror and non-mirror symmetry conditions, in which the proprioceptive drift, as reported not to go hand in hand with the ownership, didn't show any difference. This suggests that self-recognition including sense of agency and ownership could be modulated by interpersonal synchronization.

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P2.73 The use of egocentric and gravicentric cues to perceived vertical in the absence of tactile cues

Bury, N., Harris, L.R. & Bock, O. Centre for Vision Research, York University, Toronto, Canada

Human spatial orientation can be anchored in three reference frames – gravicentric (pull of gravity), allocentric (alignment of familiar visual objects) and egocentric (long body axis). In the absence of gravity, the vertical tends to be mostly aligned with the egocentric reference frame (Jenkin et al., 2005). However, it is still uncertain how vertical is determined when tactile cues to the direction of gravity, normally obtained from the support surface are absent.

Thirty-five participants were tested on ground and underwater under neutral bouyancy. On the ground, they were strapped on a padded plate; underwater, they wore a buoyancy control device, which was attached to the plate. Participants were positioned in four body postures between 0° (upright) and -135° (pitched head-down). In all conditions, vision was constrained to a circular view in which they saw a monoscopic image of a tree. Using a joystick, they adjusted it in the pitch axis such that "leaves are at the top and roots are at the bottom". The experimenter avoided any definition of "up" or "down".

On ground, 62.9% of participants were dominated by the egocentric reference frame, and 37.1% by the gravicentric frame; underwater, 65.7% of participants relied on the egocentric frame and 34.3% on gravicentric frame. 91.4% of participants were consistent in their preferred reference frame on ground and underwater.

We conclude that the weighting given to the various sensory cues that contribute to the perception of vertical is highly individual and that those that were dominated by gravity in the presence of tactile cues continued to be dominated by gravity in their absence. The vestibular system alone (without tactile cues) is sufficient for detecting the gravicentric reference frame.

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P2.74 Auditory roughness impacts the coding of peri-personal space

Taffou, M., Suied, C. & Viaud-Delmon, I. Institut de Recherche Biomédicale des Armées

Peri-personal space (PPS) is defined as the space immediately surrounding our bodies, which is critical for our interactions with the external world. This space near the body, which is coded by a dedicated network of multisensory neurons, is thought to play a role in the protection of the body. The boundaries of PPS are known to be flexible and to be modulated by the presence of threatening elements in the environment.

Recently, it has been evidenced that alarming sounds such as human screams comprise an acoustic attribute (amplitude modulation in the 30– 150Hz range), which corresponds to the perception of roughness. Roughness seems to be linked to a more intense induction of fear, behavioral gains and a higher activation in cerebral areas involved in fear and danger processing. Therefore, the presence of roughness might confer to sounds an emotional quality that should be sufficient to impact the multisensory coding of PPS.

In the present study, we explored whether auditory-tactile integration could be modified by the auditory attribute of roughness. We used a modified version of Canzoneri et al. (2012) paradigm to study peri-trunk PPS in healthy participants, comparing two meaningless looming sounds: a simple harmonic sound (f0=500Hz) and a rough sound (the same harmonic sound amplitude-modulated at 70Hz). The sounds were processed through binaural rendering so that the virtual sound sources were looming towards participants from the left part of their rear hemi-field.

We found that participants' PPS was larger in the presence of the rough sound than of the non-rough sound. These results suggest that PPS is sensitive to roughness, even expressed in a very simple way (simple harmonic sounds and not human screams or natural sounds), confirming that roughness could be an auditory attribute efficiently conveying a signal of danger to the central nervous system.

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P2.75 Neural signatures of processing noun phrases and contextual plausibility

Xia, A., Barbu, R., Singh, R., Toivonen, I. & Van Benthem, K. Institute of Cognitive Science, Carleton University Sentence comprehension involves introducing, storing, and retrieving discourse information. Indefinite noun phrases serve to introduce new discourse referents, whereas definite noun phrases are often anaphoric, triggering an internal mechanism of searching for old referents that are presumably part of the common ground (e.g., Heim, 1982). However, a definite may be used to introduce a new referent by appealing to presupposition accommodation: the process of amending the context to entail a required presupposition (Lewis, 1979; von Fintel, 2008). Thus, new information may be conveyed through assertions or presuppositions, raising the challenge of distinguishing the two as different kinds of discourse update (e.g., Gazdar, 1979).

Our study extends results from an incremental stops-making-sense task (Singh et al., 2016) by using electroencephalogram (EEG) to investigate brain activity during the processing of assertions and presuppositions in both plausible and implausible contexts. We expect part of our findings to corroborate EEG results from a similar German-language study by Burkhardt (2006), in which an N400 was elicited in implausible contexts. However, Burkhardt (2006) did not include indefinite phrases. By controlling for the addition of a discourse referent, any differences in neural signatures can be more precisely attributed to differences between definites and indefinites, and the corresponding processes involved in their interpretation.

We use abridged versions of all 128 pairs of sentences from Singh et al. (2016) as our stimuli. Preliminary data analysis from 20 participants show a main effect of definiteness, with negative deflection in the 350-400 ms time window. An effect of plausibility was also found, with a negative deflection around 400 ms and positive deflection around 600 ms in the left central and posterior regions, reminiscent of the N400/P600 complex. However, the effect of definiteness appeared stronger, suggesting that employment of presupposition accommodation.

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P2.76 Factors influencing the uptake of co-speech gestures in real-time language processing

Saryazdi, R. & Chambers, C. G. University of Toronto

Spoken language processing is known to be influenced by concurrent visual information. For example, the hand gestures produced spontaneously by talkers have been shown to facilitate listeners' auditory comprehension. The present study examines how listeners' basic ability to attend to and use these manual gesture cues is influenced by perceptual factors, such as the

nature of visual cues (small vs. large gesture) and the quality of auditory input (presence vs. absence of background noise). In two experiments, listeners watched recordings of a speaker providing instructions regarding various objects in the visual environment ("Pick up the candy"). Critical trials varied whether the speaker produced a simultaneous gesture reflecting the grasp posture used to pick up the target object. Listeners' gaze position was recorded to capture the relative ease with which the target was identified as language unfolded in real time. In Experiment 1, although listeners rarely fixated directly on the co-speech gestures, peripheral uptake of visual information speeded target identification as the sounds in the unfolding noun were heard, compared to when speech occurred without gestures. However, the benefit was mostly observed when target items were small objects. This may be because the correspondingly smaller and hence more precise-looking gestures can more effectively differentiate targets from other objects than when the target is a large object among smaller ones. In Experiment 2, background noise was added to examine whether degrading the quality of speech would increase listeners' reliance on gesture cues in a compensatory manner. Interestingly, background noise reduced listeners' use of gesture information, possibly because the increased demands on auditory processing limited the resources available for attending to or integrating visual information. Together, the results expand our understanding of how situational factors influence the degree to which visual and auditory signals are coordinated in the course of natural communicative interactions.

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P2.77 Indexing Multisensory Integration of Natural Speech using Canonical Correlation Analysis

O'Sullivan, A.E., Crosse, M.J., Di Liberto, G.M. & Lalor, E.C. Trinity College Dublin and University of Rochester, NY

Speech is a central part of our lives, and is most commonly perceived as multisensory. Indeed, integrating the auditory and visual information from a talker's face is known to benefit speech comprehension, particularly when the auditory information is degraded. However, the neural mechanisms underlying this integration are still not well understood, especially in the context of natural, continuous speech.

Recent work employing EEG to study the encoding of natural speech has indexed the benefit of congruent visual speech on the entrainment of the acoustic envelope (Crosse et al., 2015). Furthermore, they found this effect to be enhanced in challenging listening conditions, in line with the principle of inverse effectiveness (Crosse et al., 2016). This approach, however, is limited in its ability to deal with more complex representations of the speech signal. This is unfortunate given recent work demonstrating the ability to index auditory speech encoding at different hierarchical levels using EEG (Di Liberto et al., 2015). Exploiting such representations of the speech signal in a multisensory scenario could provide a more fine-grained interpretation of integration effects along the cortical hierarchy, and inform how these effects may flexibly change depending on the quality of acoustic information. Thus, our goal is to relate the multivariate EEG to a multivariate representation of the speech.

Canonical correlation analysis (CCA) is a suitable technique for this since it allows us to examine the relationship between two sets of multivariate data. Specifically, CCA finds a transform of the stimulus and response which optimizes the correlation between the two. Here, we use this approach to examine integration effects at different hierarchical levels using a spectrotemporal and phonetic feature representation of the speech. The overarching aim of the work is to develop a framework for testing hypotheses about how the temporal dynamics and articulatory information from a speaker's face help us to understand speech in challenging listening conditions.

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P2.78 Language, but not race induces vocal superiority in audiovisual emotion perception

Kawahara, M., Yamamoto, H.W. & Tanaka, A. Tokyo Woman's Christian University

For successful social interaction, humans need to perceive others' emotion from their face and voice appropriately. Recent studies have demonstrated that such audiovisual emotion perception is modulated by cultural background. Tanaka et al. (2010) showed that adult Japanese people focus on vocal expression more than adult Dutch people. In our earlier experiments, we demonstrated that such cultural differences appear during childhood; both Japanese and Dutch preschoolers judge speakers' emotion based mainly on facial expression, whereas Japanese, but not Dutch children come to focus on vocal expression with age as for in-group speakers. Then, what is the cue for Japanese children to focus on in-group members' vocal expression? One of the candidate cues is speakers' appearance (race), and the other is their language. To determine which possibility holds true, in the present study, we conducted experiments with Japanese children (5-12 years old) and adults. We showed them a video clip in which a Japanese or Dutch speaker expressed her emotion in the face and voice and asked to judge whether she is happy or angry. In the

half of the video clips, their appearance was congruent with their language (e.g., Japanese appearance – Japanese language: a speaker seems to be Japanese people and speaks Japanese language), and they were incongruent in the other half (e.g., Japanese appearance – Dutch language: a speaker seems to be Japanese people but speaks Dutch language). The results showed that Japanese 5-6 years old focused on facial expressions of speakers regardless of the speakers' appearance and language and that Japanese gradually shift their attention from facial to vocal expressions with age during childhood only when they observed Japanese appearance – Japanese language speakers or Dutch appearance – Japanese language speakers. It is suggested that speakers' language is the cue for Japanese children to focus on vocal expression in emotion perception.

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P2.79 The visual speech advantage in noise: Effects of listener age, seeing two talkers and spatial cuing

Beadle, J., Davis, C. & Kim, J The MARCS Institute, Western Sydney University

In noisy conditions, seeing a talker's face facilitates speech recognition (the visual speech advantage). Movement from an individual's face and mouth supplements congruent auditory information, allowing better speech perception. However, what happens when two talkers (one relevant and one irrelevant) are presented? Would seeing another talker reduce the visual advantage for younger and older listeners? And would cuing the relevant talker overcome this? To investigate these questions, we recruited 24 younger adults (10 Females, MAge=24) and 24 older adults (12 Females, MAge=71) for a speech recognition experiment. Spoken sentences were mixed with speech shaped noise at -1 & -4dB SNRs and randomly presented in four visual display conditions: Baseline (a still face image); Standard visual speech (a video of a single relevant talker); Valid cue (videos of relevant and irrelevant talkers side-by-side); and Ambiguous cue (same as condition 3). The cue consisted of a white rectangle that appeared before the sentence and remained visible until the trial finished. The valid cue surrounded only the relevant talker; the ambiguous cue both videos. Participants were instructed to attend to the space inside the rectangle and type what they heard. Overall, recognition rates were highest for the Standard condition, and were poorer than Standard but better than Baseline when two talkers were presented. Younger adults performed better than older adults. Younger adults benefited from the Valid cue; older adults did not. The results suggest that focusing on a relevant talker is necessary for auditory and visual speech signals to integrate and provide a visual speech advantage. Further, older adults seem to be more susceptible to distraction from an irrelevant talker, even when a salient cue directing visual-spatial attention towards the relevant talker is presented. The role of attention in auditory-visual speech perception across the lifespan will be discussed.

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P2.80 Audiovisual Integration of Subphonemic Frequency Cues in Speech Perception

Plass, J., Brang, D., Suzuki, S. & Grabowecky, M. Department of Psychology, University of Michigan

Visual speech can facilitate auditory speech perception, but it is unclear what visual cues contribute to these effects and what crossmodal information they provide. Because visible articulators (e.g., mouth and lips) shape the spectral content of auditory speech, we hypothesized that listeners may be able to infer spectrotemporal information from visual speech. To uncover statistical regularities that would allow for such crossmodal facilitation, we compared the resonant frequencies produced by the front cavity of the mouth to the visible shape of the oral aperture during speech. We found that the time-frequency dynamics of this oral resonance could be recovered with unexpectedly high precision from the changing shape of the mouth. Because both frequency modulations and visual shape properties are neurally encoded as mid-level perceptual features, we hypothesized that perceptual learning of this correspondence could allow for spectrotemporal auditory information to be recovered from visual speech without reference to higher-order speech-specific (e.g., phonemic or gestural) representations. Isolating these features from other speech cues, we found that speech-based shape deformations enhanced sensitivity for naturally co-occuring frequency modulations, although neither was explicitly perceived as speech and, therefore, unlikely to be represented with a speech-specific code. To test whether this type of correspondence could be used to enhance speech intelligibility, we degraded the spectral content of spoken sentences so that they were nearly unintelligible, but their amplitude envelope was preserved. Visual speech produced superadditive improvements in word identification, suggesting that obscured spectral content could be recovered from visual speech. This enhancement superseded enhancements observed when the amplitude envelope was degraded and spectral content preserved, suggesting that visual speech provided spectral information independently of any higher-order speech information that would have affected both conditions equally. Together, these results suggest that the perceptual system exploits statistical relationships between mid-level audiovisual representations of speech to facilitate perception.

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P2.81 Using infant-directed speech to convey meaning: prosodic correlates to visual properties of objects

Walker, P. & Bremner, G. Lancaster University

Despite traditional assumptions that prosody contributes only to the structural organisation of spoken language, increasing evidence suggests that it plays a fundamental role in the communication and interpretation of ambiguous word meaning. Specifically, recent research suggests that speakers manipulate prosody in a way that reflects known crossmodal correspondence between visual and auditory sensory channels, such as the relationship between auditory pitch and visual brightness (i.e. higher-pitched sounds are associated with brighter objects than their lower-pitched counterparts). Given the prosodically rich and variable nature of infantdirected speech (IDS) in the company of novel language users, we predict that users of IDS manipulate prosody in an attempt to convey semantic information paralinguistically. To further establish how prosody is used in this enterprise, we explored the extent to which infant-directed speakers talk about novel objects that differ in one of five visual dimensions: size, angularity, brightness, height and thinness (all of which have been found to elicit visual-auditory crossmodal correspondences). In this experiment, adult users of IDS verbalised simple sentences containing a novel word (e.g. "Look at the timu one.") in the presence or absence of meaning. The findings throw light on the functional significance of crossmodal correspondences in IDS.

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P2.82 Is integration of audiovisual speech fixed or flexible?

Tiippana, K., Kurki, I. & Peromaa, T. University of Helsinki

Both auditory (A) and visual (V) articulation cues can be used in speech perception. Often, one sensory modality has a higher signal-to-noise ratio, providing more informative cues. Statistically optimal integration would weigh the cues according to how much information each modality provides, thus requiring an accurate estimate of the informativeness of the cues in the stimulus. Here, we studied the optimality of audiovisual (AV) speech integration using subthreshold summation paradigm. Moreover, we investigated the effect of a priori knowledge on integration: Is optimal weighting possible only when the observer knows the relative informativeness of A and V cues?

Thresholds for discriminating syllables [ka] and [pa] were measured with the method-of-constant-stimuli for auditory, visual and audiovisual stimuli presented in white noise by finding the auditory intensity and visual contrast level corresponding to 74% correct responses. Thresholds were measured in five stimulus conditions: unisensory A and V, and three different AV ratios. The five stimulus conditions were presented either randomly interleaved, or in blocks so that the observer knew which condition was measured. Integration was assessed by comparing the intensity of A and V components in an AV stimulus at threshold to unisensory thresholds. An optimal model predicts quadratic summation, i.e. AV thresholds proportional to the square root of the sum of squared A and V intensities at threshold. A suboptimal model with fixed weights predicts higher unisensory thresholds and, paradoxically, linear summation.

We found roughly quadratic summation of AV thresholds in both interleaved and blocked experiments. This suggests that cue weighting in AV integration is optimal and does not require a priori knowledge. However, the thresholds in the interleaved experiment were overall about 10% higher compared to the blocked experiment. This implies that estimating the cue information value without a priori knowledge imposes a general processing cost.

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P2.83 Perceiving your own shadowers' speech

Chee, S., Dorsi, J., Rosenblum, L.D. & Dias, J.W. University of California - Riverside

Listeners often imitate subtle aspects of a talker's speech when producing a spoken response (e.g., Goldinger, 1998). This phonetic convergence has been observed not only with audio speech, but also with visual speech. Shadowed lipread speech sounds more similar to a shadowed talker's speech than does unshadowed (read) speech (Miller, Sanchez, and Rosenblum, 2010). Phonetic convergence is also perceived across modalities in that raters judge audio speech based on shadowed responses of lipread speech from a talker as more similar to that talker's lipread speech. Both audio and visual phonetic convergence may serve to enhance mutual comprehension during conversation (e.g., Pardo, 2006). In fact, it may be that converging toward a specific talker's speech makes

understanding easier for that talker. To test this possibility, experiments were conducted to examine whether talkers hear their shadowers better than individuals who shadowed different talkers. An initial study explores whether a talker would better understand shadowers who were asked to shadow the audio speech produced by that talker. Ten perceivers were recorded uttering 320 words. Groups of four shadowers were asked to listen to the perceiver's words and say each 'quickly and clearly' as they were being recorded. After a few months, the original perceivers returned and listened to words recorded by their own shadowers, as well as shadowers who listened to another perceiver's words. Perceivers heard the words in noise and were asked to identify and respond with what the word was. Initial results indicate that perceivers more easily understood words produced by shadowers who shadowed them, suggesting that phonetic convergence may serve comprehension. Follow up experiments will test whether this same advantage holds for audio words based on shadowing responses of lipread speech, and whether a talker can more easily lipread words if those words were shadowed from that talker.

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P2.84 Examining Modality Differences in Timing to test the Pacemaker Explanation

Williams, E.A., Yüksel E.M., Stewart, A.J. & Jones, L.A. University of Manchester

We investigated the classic effect that "sounds are judged longer than lights", when the two modalities are of equal duration (Goldstone et al., 1959). Recently, durations of vibrations have been found to be judged somewhere between the two (Jones et al., 2009). This pattern has also been found for temporal difference thresholds, where sensitivity is highest for sounds, followed by vibrations, and lowest for lights (Jones et al., 2009). Scalar Expectancy Theory explains these findings as the result of a central pacemaker which pulses at a faster rate for sounds, followed by vibrations, and slowest for lights (Wearden et al., 1998; Jones et al., 2009). The current work aimed to test this assertion by replicating the estimation and threshold tasks of Jones et al. (2009) and correlating performance across tasks for each modality.

We used this same approach to investigate the filled-duration illusion: continuous sensory stimuli are judged to be longer than 'unfilled' stimuli, which are delineated by short beeps or flashes. Again, this difference presents itself in both estimation and threshold tasks (Wearden et al., 2007; Rammsayer, 2010), and it has similarly been argued that the pacemaker pulses at a faster rate for filled than unfilled stimuli (Wearden et al., 2007). To round off these experiments, we performed computational modelling to investigate an alternative explanation to pacemaker rate.

Our results can be summarised as three key findings. First, the classic patterns of pacemaker rates are not as pervasive as originally thought; up to 27% of participants exhibited alternative patterns. Second, if pacemaker rate is a driving factor for estimates and thresholds, its effect appears to be greater for unfilled than for filled intervals. Finally, differences in internal variability could be a contributing factor to estimation-slope effects between stimulus modalities and stimulus types, but it cannot solely explain these differences.

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P2.85 Synesthesia: Seeing the world differently, a phenomenological report Steen, C. J.

Touro College and University System

On July 16, 1915, the American painter Charles Burchfield told another of his secret perceptions to his journal. He wrote: "It seems at times I should be a composer of sounds, not only of rhythms and colors. Walking under the trees, I felt as if the color made sound." There are stories about some synesthetes who were shunned when they blurted out their secret perceptions – as it is said that van Gogh was by his piano teacher. Others were diagnosed as being almost mad. A few lucky ones, like Kandinsky, knew that they were not alone and that their joined perceptions had a name so they were free to explore, and create, from their experiences. Today we know that synesthetic perceptions are real and experienced by about 1 person in 23. But what do synesthetes actually experience?

I am a synesthete with five different forms of synesthesia. I have the common forms of colored graphemes, and moving, colored sounds, and the rarer forms of colored smells, and moving, shaped, colors from touch or pain. I use my experiences to create my art, and to diagnose my health. My work is in several museums and the Library of Congress.

In my paper I will discuss some of the 60 known common, and rare, forms of synesthesia, show what synesthetes see, and mention some ways in which synesthesia can be used to navigate in the world besides providing artistic inspiration. I will show examples of my synesthetic perceptions by means of a few very short videos that animate the linear Kluver form constants diagrams to show what synesthetes really see. I believe that scientists can learn a great deal from the phenomenology of synesthetic perceptions and the different ways synesthetes use their abilities.

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P2.86 Perceived depth reversal in a motion parallax display when observers fixated on different depth planes

Sakurai, K., Neysiani, N.Z., Beaudot, W. & Ono, H. Tohoku Gakuin University

When an intersection of visual axes is not on the screen of an observerproduced motion parallax display, a head movement adds common motion to the stimulus elements on the retinae. We previously reported the perceived depth order was affected when this common motion was artificially added to a motion parallax display (Sakurai, Furukawa, Beaudot, Ono, 2017). We investigated whether the common motion caused by real depth difference of fixation affects the perceived depth order. The randomdot patterns subtended 11 deg (height) x 12 deg (width) were presented on the screen of motion parallax display, which produced 2 cycles of sinusoidal corrugated surfaces with 1.75, 3.5, 7 cm (from peak to trough) depth. Through polaroid filters, 5 observers monocularly viewed the random-dot patterns at a viewing distance of 114 cm and binocularly fixated a red LED light at viewing distances of 57, 80.4, 114, 161.2, 228 cm with moving their heads back and forth 12 cm laterally. The task was to report whether the region immediately below the fixation point appeared convex or concave. In the conditions of 3.5 and 7 cm depth at viewing distances of 114, 161.2, 228 cm, the apparent depth order consistent with that defined by the motion parallax alone reached more than 90 % responses. In the same conditions at viewing distances of 57, 80.6 cm, however, the apparent depth order consistent with that defined by the motion parallax dropped to 70 % responses. This was not the case in the condition of 1.75 cm depth. These results suggest that there is a conflict between depth cues of motion parallax and retinal velocity in the conditions at 57, 80.6 cm viewing distances.

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P2.87 Central fatiguing mechanisms are responsible for decreases in hand proprioceptive acuity following shoulder muscle fatigue Sadler, C.M. & Cressman, E.K.

University of Ottawa

Muscle fatigue is a complex phenomenon that consists of central and peripheral mechanisms which contribute to local and systemic changes in muscle performance. These effects seem to alter processing of afferent feedback from local and non-local muscles, yet it is currently unclear how proximal muscle fatigue affects proprioceptive acuity of the distal limb. The purpose of the present study was to assess the effects of shoulder muscle fatigue on participants' ability to judge the location of their hand using only proprioceptive cues. Participants' (N = 16) limbs were moved outwards by a robot manipulandum and they were instructed to estimate the position of their hand relative to one of four visual targets (two near, two far). This estimation task was completed before and after a repetitive pointing task was performed to fatigue the shoulder muscles. To assess central versus peripheral effects of fatigue on the distal limb, the right shoulder was fatigued and proprioceptive acuity of the left and right hands were tested. Results showed that there was a significant decrease in proprioceptive acuity of both hands after the right shoulder was fatigued, with no change to the variability of proprioceptive estimates. A control experiment (N = 8), in which participants completed the proprioceptive estimation task before and after a period of quiet sitting, ruled out the possibility that the observed bilateral changes in proprioceptive acuity were due to a practice effect. Together, these results indicate that proximal muscle fatigue decreases proprioceptive acuity in both hands, suggesting that central fatigue mechanisms are responsible for changes in afferent feedback processing of the distal limbs.

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P2.88 Co-designing Serious Games in the Surgical Environment to Address Multisensory Communication Styles and Team Experiences Jordan, C.

OCAD University

Preventable medical errors in the operating room account for the eighth leading cause of death in North America. While process improvements have been made, the larger system of communications and information exchanges amongst surgical team members remain poorly designed. Communication within the operating room must be clearly and efficiently delivered in order to prevent medical errors, mortality or future health complications for the patient. Current forms of communication are generally invisible and ambiguous during high-stress situations or medical

emergencies, ensuring this system offers a false sense of safety and encourages similar mistakes to occur in the future. In order to decrease medical errors and improve patient safety, the complexities between verbal, visual, tactile, sonic and spatial understanding amongst team members must be considered. As technical skills are prioritized within the surgical environment, communication is considered a non-technical skill with minimal training provided. A gap remains in the ability of teams to learn and safely apply communication skills within the surgical environment without compromising patient safety. To create a more engaging learning environment, the use of serious games can aid in the development and understanding of multisensory communication styles. Serious games provide a safe and reliable environment where teams can practice real-life scenarios through role play, time constraints, humour and competition. If mismatches in communication techniques and human behaviour amongst team-members can be identified and the situation awareness of the team can be adaptable to the requirements of the procedure, surgical safety can be improved.

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P2.89 Do movement sequences and consequences facilitate dual adaptation of opposing visuomotor rotations?

Ayala, M.N. & Henriques, D.Y.P. York University

Investigating the factors that affect the ability to learn or regain motor skills within a limited time-frame are of great interest to both sports and rehabilitation domains. When planning movements, the human central nervous system can actively compensate and adapt to two or more distinct perturbations simultaneously ("dual adaptation") but this is only possible when each visuomotor map is associated with a sufficient contextual cue. It has recently been shown that cueing the motor system by including a leadin or follow-through movement (or even a sequence including both) prior to the perturbed movement, can facilitate learning of opposing force-field perturbations. Thus, the additional movement segment predicts the appropriate visuomotor map for the task. Here, we investigate whether that additional movement sequence requires an active motor component or if a visual consequence is sufficient to facilitate dual adaptation of opposing visuomotor rotations. In the sequence experiment, participants experienced opposing rotations within the same experimental block, each associated with a distinct sequence (i.e. arm moves to the left or right). To see whether a passive visual consequence was sufficient, in the follow-up experiment, each rotation was associated with a target consequence (i.e. target moves to the left or right). To compare the extent of dual learning, two more groups each learned a single rotation with the same previous sequence-rotation association. Together these findings show whether active movement sequences and passive consequences are incorporated into motor planning and execution, and can thus facilitate dual learning of opposing visuomotor rotations.

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P2.90 Crossmodal correspondences are spontaneously used to communicate in a coordination task

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Prior research on crossmodal correspondences has shown that magnituderelated stimuli features from different sensory modalities are consistently associated and lead to facilitation of individual perceptual performance [1-4]. Here, we tested whether people rely on these crossmodal associations to communicate non-verbally in social interactions.

In the context of social interactions, actors have been found to send nonverbal signals to support coordination: They systematically modulate visually perceivable parameters of their goal-directed movements (e.g., amplitude) in a way that allows co-actors to more easily predict the goal location of these movements [5-7]. Thus, actors send visual signals referring to visual locations. In the present study [8], we investigated whether non-verbal signals are also used to communicate across different sensory modalities.

To this end, two participants – seated at opposite sides of a table and unable to observe each other – were instructed to perform reaching movements to one out of three target locations aligned horizontally on the table in front of each participant. Their coordination goal was to move to corresponding target locations. Only one participant ('Leader') received information about the correct target location whereas the other participant ('Follower') did not receive any information. The Leader moved first, after a tone had marked the beginning of the trial. A second tone was triggered when the Leader arrived at the target. Subsequently, the Follower attempted to move to the corresponding target.

The results showed that Leaders systematically adjusted the duration of their actions, thereby modulating the pause between the start tone and the target arrival tone (Exp. 1) or the duration of the target arrival tone (Exp. 2), to communicate the correct target location to uninformed Followers.

Specifically, Leaders used longer auditory durations to signal farther visual locations.

These findings demonstrate that people spontaneously use magnituderelated crossmodal associations to communicate non-verbally during interpersonal action coordination [9].

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P2.91 Explicit contributions to visuomotor adaptation transfer between limbs regardless of instructions

Bouchard, J.M. & Cressman, E.K. University of Ottawa - School of Human Kinetics

Both implicit and explicit processes contribute to visuomotor adaptation (i.e., adapting one's movements in response to experiencing altered visual feedback of the hand's position). Moreover, visuomotor adaptation seen in the trained hand transfers to the untrained hand. In the current study, we asked if both implicit and explicit processes transfer between limbs and if transfer is dependent on being provided with explicit instructions on how to counteract the viusomotor distortion. To probe the permanency of implicit and explicit contributions to visuomotor adaptation, we tested for retention on a second testing day (Day 2). Twenty eight right-handed participants were divided into 2 groups (Strategy and Non-Strategy). All participants reached to three visual targets with a cursor on a screen that was rotated 40° clockwise relative to their hand motion. Participants in the Strategy group were instructed on how to counteract the visuomotor distortion. Following rotated reach training, participants completed two types of reaches without visual feedback. Specifically, participants: (1) aimed so that their hand landed on the target (to assess implicit contributions) and (2) used what was learned during reach training so that the cursor landed on the target (to assess explicit contributions). These no-cursor trials were performed with the left (trained) and right (untrained) hands immediately after reach training and again 24 hours later. As expected, results revealed that the Strategy group displayed greater explicit contributions and less implicit contributions in comparison to the Non-Strategy group in the trained hand after training. In addition, explicit contributions were transferred to the untrained hand for both groups, and were retained on Day 2 in contrast to implicit contributions, which were not transferred between limbs, or retained for either group. Together, these results suggest that the intermanual transfer of visuomotor adaptation may be driven by explicit processes that are relatively stable over time.

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P2.92 Contributions of online and offline processes to reaching in typical versus novel environments

Wijeyaratnam, D.O., Chua, R. & Cressman, E.K.

University of Ottawa

Human movements are remarkably adaptive, such that we are capable of completing movements in a novel environment with similar accuracy to those performed in a typical environment. In the current study we examined if the control processes underlying movements under typical and novel visuomotor conditions are comparable. Sixteen participants were divided into 2 groups, one receiving continuous visual feedback during all reaches (CF), and the other receiving terminal feedback regarding movement endpoint (TF). Participants trained in a virtual environment by performing 150 reaches to 3 targets when (1) a cursor accurately represented their hand motion (i.e., typical environment) and (2) a cursor was rotated 45 degrees clockwise relative to their hand motion (i.e., novel environment). Analyses of end-point based measures over time revealed that participants were able to demonstrate similar levels of performance (i.e., movement time and angular errors) regardless of visual feedback or reaching environment by the end of reach training. Furthermore, a reduction in variability across several measures (i.e., reaction time, movement time, time to peak velocity, time after peak velocity, and jerk score) over time showed that participants improved the consistency of their movements in both reaching environments. However, participants took more time and were less consistent in initiating their movements when reaching in a novel environment compared to reaching in a typical environment, even at the end of the training trials. As well, angular error variability was also consistently greater when reaching in a novel environment across trials, and within a trial (i.e., when comparing error variability at different proportions of the movement trajectory: 25%, 50%, 75% and 100%). Together, the results suggest a greater contribution of offline control processes and less effective online corrective processes when reaching in a novel environment compared to when reaching in a typical environment.

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P2.93 Interindividual Differences in Eye Movements Made During Face Viewing Are Consistent Across Task And Stimulus Manipulations Wegner-Clemens, K., Rennig, J., Magnotti, J.F. & Beauchamp, M.S. Baylor College of Medicine

There is substantial interindividual variability in the eye movements made by humans viewing faces: some participants spend more time fixating the mouth of the viewed face, while others spend more time fixating the eyes. To determine the consistency of these interindividual differences, 41

participants viewed faces under different stimulus/task manipulations while their eye movements were recorded with an infrared eye tracker (EyeLink 1000 Plus, SR Research Inc.). The two stimulus conditions consisted of a dynamic face condition (two-second videos of one of four talkers speaking an audiovisual syllables) and a static face condition (still frames from the same videos). The two task conditions consisted of a speech task (reporting the identity of the monosyllable) and a gender task (reporting the gender of the talker's face). Fixation data was subjected to a two-dimensional principal components analysis (PCA). The first PC (PC1) accounted for 42% of the total variation and consisted of a positive peak around the eyes of the talker and a negative peak around the mouth. The PC1 values was for each participant was correlated across conditions. For the same stimulus/different task manipulation (dynamic stimuli + speech vs. gender task) there was a significant correlation between participant values (r = 0.55, p = 0.0001). For the different stimulus/same task manipulation (dynamic vs. static stimuli + gender task), there was also significant correlation between participant values (r = 0.53, p = 0.0003). For the different stimulus/different task manipulations (dynamic stimulus with speech task vs. static stimulus with gender task) the correlation was weaker (r = 0.31, p = 0.05). These results demonstrate that participants' internal preferences for face viewing interact with the viewed face and the behavioral demands of the task to determine eye movement behavior.

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P2.94 The relative role of visual self-motion feedback and biological sex identification on the sense of self

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What constitutes the sense of self? In the last twenty years, there has been a rise in experimental research on bodily self-consciousness and the sense of self. Previous experiments such as the rubber hand illusion and wholebody illusions have focused on interpreting embodiment, an aspect of the sense of self, under the representational approach, which focuses on neural representations to explain what constitutes the sense of self. While the representational theory focuses on neural representations, the sensorimotor theory focuses on sensorimotor functions and voluntary action. Although there is no consensus among researchers of their definitions, body schema is generally regarded as an unconscious, bottom-up, dynamic representation, relying on proprioceptive information from the muscles, joints, and skin during self-motion. On the other hand, the body image is a more conscious, top down, cognitive representation, incorporating semantic knowledge of the body and ones identity including biological sex. Here we

investigated the degree to which biological sex and self-motion have a role in the visual representation of the self. To determine the relative role of biological sex and visual self-motion on the sense of self, we constructed a novel virtual reality experiment that systematically varied an avatar's sex and motion, after which participants recorded judgments about the relationship between themselves and the avatar. Over multiple trials, participants were presented with pairs of avatars that visually represented the participant ("self avatar"), or another person ("opposite avatar"). Additionally, the avatars' motion either corresponded to the participant's motion, or was decoupled from the participant's motion. The results show that participants identified with i)"self avatars" over "opposite avatars", ii) avatars moving congruently with self motion over incongruent motion, and importantly iii) identification with the "opposite avatar" over the "self avatar" when the opposite avatar's motion was congruent with self-motion. Our results suggest that both biological sex and self motion are relevant to the body schema and body image and that congruent bottom up visual feedback of self-motion is particularly important for the sense of self and capable of overriding top-down self-identification factors such as biological sex.

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P2.95 Multisensory stochastic facilitation: Effect of thresholds and reaction times

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The concept of stochastic facilitation suggests that the addition of precise amounts of white noise can improve the perceptibility of a stimulus of weak amplitude. We know from previous research that tactile and auditory noise can facilitate visual perception, respectively. Here we wanted to see if the effects of stochastic facilitation generalise to a reaction time paradigm, and if reaction times are correlated with tactile thresholds. We know that when multiple sensory systems are stimulated simultaneously, reaction times are faster than either stimulus alone, and also faster than the sum of reaction times (known as the race model). Five participants were re-tested in five blocks each of which contained a different background noise levels, randomly ordered across sessions. At each noise level, they performed a tactile threshold detection task and a tactile reaction time task. Both tactile threshold and tactile reaction times were significantly affected by the background white noise. While the preferred amplitude for the white noise was different for every participant, the average lowest threshold was obtained with white noise presented binaurally at 70db. The reaction times were analysed by fitting an ex-Gaussian, the sum of a Gaussian function and an exponential decay function. The white noise significantly affected

the exponential parameter (tau) in a way that is compatible with the facilitation of thresholds. We therefore conclude that multisensory reaction time facilitation can, at least in part, be explained by stochastic facilitation of the neural signals.

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