10th International Multisensory Research Forum

June 29 -July 2, 2009

the City College of New York

International Multisensory Research Forum

IMRF 2009
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Key Partners and Sponsors

We would like to acknowledge and thank the following institutions and companies for kindly contributing to this 10th Annual Meeting of the IMRF:

Acknowledgements
The local organization team consisted of Sophie Molholm, John J. Foxe, Edel Flynn, Hans-Peter Frey, Ian Christopher Fiebelkorn, Joshua Nelson Lucan, Gabriella Musacchia, Arnaud Falchier, Natalie Russo & John Butler.

Cover Image:
Image courtesy of Professor Sydney C. Van Nort, archivist of the City College of New York. Many of the grotesque sculptures designed by G. Grandellis decorating the Collegiate Gothic buildings are engaged in activities that reflect the academic pursuits of the community. See pages 12 and 13 for a historical note on the City College of New York

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IMRF Welcome

Dear IMRF delegates,

We are very pleased to host the 10th annual meeting of the International Multisensory Research Forum this year at the City College of New York. As this conference program attests, IMRF brings together researchers from a broad swath of disciplines with a common interest in the important and intriguing problem of how the senses interact to drive perception and behavior.

With its strong commitment to the Neurosciences, City College is a most suitable venue for this gathering. Systems neuroscience is a strong and rapidly growing area of research at the City College of New York. Just two buildings down from where we gather a Neuroscience Center is being built that will promote intramural collaboration and foster the development of ideas that span across disciplines.

A few words on the program: This year there were universally strong proposals for symposia, and the vote from the 9 International Committee members was very close. The resulting symposia present a very interesting set of topics that promise to be highly engaging and edifying. The general oral sessions cover an extensive array of topics and we believe there is something for everyone in the program. There were many truly excellent applications for the graduate student fellowships; to the 7 final awardees we offer our heartfelt congratulations. They will present their research in the graduate student award session. This promises to be very interesting, and affords an opportunity to see the up-and-coming scientists in the field. Finally, we are very fortunate to have Dr. Dora Angelaki, Dr. Jon Kaas, and Dr. Nikos Logothetis as our keynote speakers this year, and to them we extend a very warm welcome.

Each year a different member of our multisensory community organizes this conference in collaboration with an International Advisory Committee and a local group of organizers. This year I have been very fortunate to have an active International Committee and a highly dedicated group of local organizers. They are listed elsewhere in the program. There are however a couple members of the local committee that have gone well beyond the call of duty and deserve to be singled

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out. One is Edel Flynn, our laboratory administrator (for the Cognitive Neurophysiology Laboratory and the Children's Research Unit), and the other is Dr. des. Hans-Peter Frey, a post-doctoral fellow at the CNL who has been responsible for website management and registration. I have also received indispensable advice from Dr. John Foxe and Dr. David Shore, organizers of previous IMRF conferences, and I would like to acknowledge their contributions as well. Thank you to all the members of the International Committee and the local organizers for all your work and your willingness to volunteer for whatever task came along. Your contributions have been invaluable.

IMRF delegates, we wish you all a warm welcome to New York City, The City College of New York, and the 10th annual meeting of the International Multisensory Research Forum!

With warm regards

Sophie Molholm, Ph.D.
Conference Chair

City College of New York, United States
Associate Professor
Program in Cognitive Neuroscience
Psychology Department

General Information
The conference will be held in the Great Hall of Shepard Hall, City College, New York. Registration and all poster and oral presentations will take place in Shepard Hall daily. Please see the conference schedule on page 11 for further detail. Refreshments will be provided throughout the day with lunch taking place on the Quadrangle in front of Shepard Hall. However, if it rains, lunch will be held indoors.

Registration and conference material
Conference delegates can register at the IMRF desk in the Great Hall all day on the first day of the conference and from 8:30 – 9:00 on the following days. You will receive your conference pack once you have registered.

Internet access
Internet access will be available in the Great Hall of Shepard Hall.

Instructions for presenters of talks
All talks excluding the Graduate Symposium will be 15 minutes plus 5 minutes for discussion. The graduate student award talks will be approximately 12 minutes with 3 minutes designated for discussion. The auditorium will be equipped with an LCD projector, loudspeakers, overhead projector and laptop computers (PCs). We ask presenters using PowerPoint to download and check their presentation *before* the beginning of the session. Presenters can also bring their own laptops, but in any case please have a copy of your talk ready in a CD or memory stick. We ask presenters wishing to use any other kind of equipment during their talk to contact the organizers at least two weeks before the meeting.

Instructions for presenters of posters
Maximum poster size is 35 inches (100cm) tall by 55 inches (150cm) wide, landscape orientation.

How to get to City College

By Train

- Take the #1 or #9 local to 137th Street and Broadway; walk up 138th Street three blocks to Convent Avenue.

- Take the "A" or"D" express, or the "B" or "C" local to 145th Street and St. Nicholas Avenue, walk west one block to 145th Street and Convent Avenue, then south to 138th Street.

- Take the #4 or#5 express or #6 local to 125th Street and Lexington Avenue, change there for the M-100 or M-101 bus to Amsterdam Avenue and 138th Street, walk east one block to Convent Avenue. Metro North to 125th Street and Park Avenue, change there for the M-100 or M-101 bus to Amsterdam Avenue and 138th Street, walk east one block to Convent Avenue.

By Bus

- M-18 to 138th Street and Convent Avenue.

- M-4 or M-5 to Broadway and 137th Street, walk up 138th Street three blocks to Convent Avenue.

- M-100 or M-101 to Amsterdam Avenue and 138th, walk east one block to Convent Avenue.

- M-101 to 135th and Amsterdam Avenue and walk north to 138th Street, then east one block to Convent Avenue.

- BX-19 to 145th and Convent Avenue, walk south on Convent Avenue to 138th Street.

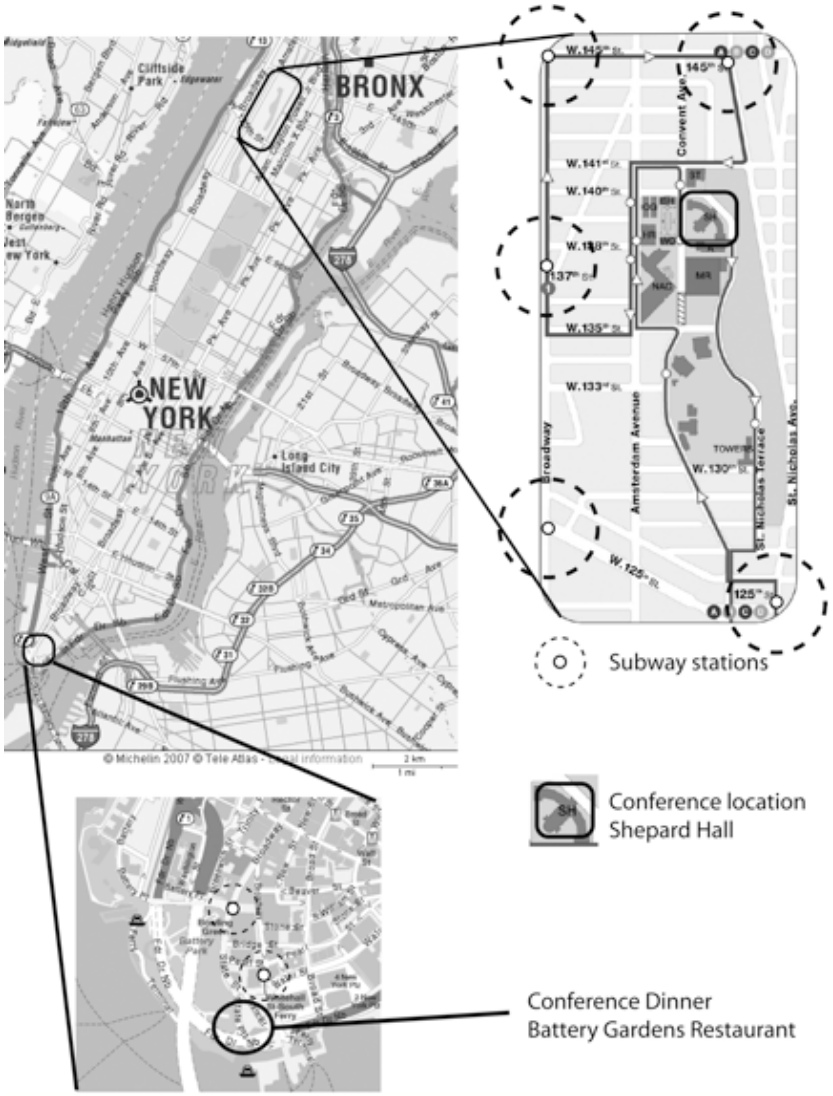
By Car

- From the West Side: Westside Highway travelling north, exit at 125th Street, right to Amsterdam Avenue; left to 133rd Street right one block to Convent Avenue.

- ***From the Westside*** Highway traveling north or south: Exit at 125th Street, cross Broadway, one block; left onto Amsterdam Avenue; right onto 133rd Street one block; left onto Convent Avenue.

- ***From the East Side:*** From the FDR or the Triborough Bridge to Harlem River Drive, exit at 135th Street to end, turn right on St. Nicholas Avenue, then left onto 141st Street and turn left on Convent Avenue to reach the campus.

Map of Manhattan, City College Campus and nearby subway stations



Social Highlights

- BBQ style food will be provided on campus - Tuesday, 30th June from 5:30 – 7:30p.m.

- A banquet dinner will be held in Battery Gardens Restaurant at 7:00p.m. on Wednesday, July 1st. Please see below for further information on where the restaurant is and how to get there via public transport. Conference delegates are kindly asked to make their own travel arrangements to and from the restaurant.

Battery Gardens Restaurant,
Address: On The Harbor, Inside Battery Park, Opposite 17 State Street ***Phone:*** (212) 809 – 5508

Where is it?
Battery Gardens is located inside Battery Park;.(across the street and about 1 block inside the Park opposite 17 State Street) at the very southernmost tip of Manhattan. As you face South from State Street, it is to the right (west) of the Staten Island Ferry Terminal and the US Coast Guard Building. See map on page 10.

Directions
Trains
Take the 1 train (runs along Broadway) to South Ferry Station. When taking the # 1 train you must be in one of the first five cars to exit at South Ferry Station. Walk into the park to the right facing the Staten Island Ferry Terminal. Battery Gardens is about a block West of the station.

Buses
M1, M6, M13 all terminate on State Street in front of the Staten Island Ferry Terminal. Walk into the park to the right when facing the Staten Island Ferry Terminal.

IMRF 2010
Mark your calendar's now for next year's meeting, to be held at the University of Liverpool, from 16th June – 19th June 2010. Symposia proposals are being accepted, please email the organizer Georg Meyer at G.Meyer@liverpool.ac.uk for further details.

Historical note on City College

City College is the oldest of the 23 schools in New York's City University system. Founded as the Free Academy of the City of New York in 1847 by Townsend Harris, a prominent New York merchant and America's first ambassador to Japan, City College began as an educational and political experiment by providing access to higher education for bright young men — and later women — from working class and immigrant families who could not afford private college.

It moved to Harlem in 1906, following the opening of the first line of subway. Indeed, architect George B. Post used debris from the subway tunneling to build the Gothic quadrangle. Each building mimics one part of a medieval walled city, with Shepard Hall (on the east side of the campus) playing the role of the cathedral.

At the time of its move to Harlem, the college was becoming predominantly Jewish and, in the early years of the 20th century, increasingly radical, earning it the nickname the 'Harvard of the Proletariat'. Many of those educated by the poor mans Harvard distinguished themselves in various fields, including the former U.S. secretary of state Colin Powell, former U.S. Supreme Court justice Felix Frankfurter, writers Walter Mosley and Paddy Chayefsky, actors Samuel Zero Mostel and Richard Schiff, the scientist Jonas Salk, along with two Rhodes Scholars and nine Nobel laureates:

- Julius Axelrod 1933 - 1970 Nobel laureate in Medicine
- Kennethe Arrow 1940 - 1972 Nobel laureate in Economics
- Robert J. Aumann 1950 - 2005 Nobel laureate in Economics
- Herbert Hauptman 1937 - 1985 Nobel laureate in Chemistry
- Robert Hofstadter 1935 - 1961 Nobel laureate in Physics
- Jerome Karle 1937 - 1985 Nobel laureate in Chemistry
- Arthur Kornberg 1937 - 1959 Nobel laureate in Medicine
- Leon M. Lederman 1943 - 1988 Nobel laureate in Physics
- Arno Penzias 1954 - 1978 Nobel laureate in Physics

The City College of New York continues to provide low-cost, high-quality education for New Yorkers in a wide variety of disciplines. Over 15,000 students pursue undergraduate and graduate degrees

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in the College of Liberal Arts and Sciences; the School of Architecture, Urban Design and Landscape Architecture (SAUDLA); The School of Education; The Grove School of Engineering, The Sophie Davis School of Biomedical Education.

Conference Schedule

	Mon 29th	Tues 30th	Wed 1st	Thurs 2nd
8:30-9:00	Registration- open all day	Registration	Registration	
9:00-9:30	symposium 1 **Multisensory processing in flavour perception chaired by Garmt Dijksterhuis**	posters-2 (coffee/snack)	posters-3 (coffee/snack)	posters-4 (coffee/snack)
9:30-10:00				
10:00-10:30				
10:30-11:00		symposium 3 **An embodied view of multisensory speech chaired by Asif Ghazanfar**	symposium 5 **The development of multisensory integration chaired by David Lewkowicz**	oral session - 4 **Modeling and brain mapping**
11:00-11:30	posters-1 (coffee)			
11:30-12:00				
12:00-12:30				
12:30-1:00	Lunch- buffet at quad	light lunch-wraps and bevgs	Lunch- buffet at quad	Lunch- buffet at quad business meeting 1:00-2:00
1:00-1:30				
1:30-2:00		symposium 4 **Graduate student award talks**		
2:00-2:30	Keynote-1 Dora Angelaki		oral session - 3 **Development**	symposium 6 **Plasticity and synergy in multisensory integration chaired by Barry Stein**
2:30-3:00				
3:00-3:30	Oral Session - 1 **Attention**			
3:30-4:00		Keynote-2 Jon Kaas		
4:00-4:30			coffee/snack break	coffee/snack break
4:30-5:00	coffee/snack break	oral session - 2 **Body schema**	Keynote-3 Nikos Logothetis	oral session - 5 **other**
5:00-5:30	symposium 2 **New Insights into crossmodal plasticity chaired by Alex Meredith**			
5:30-6:00		BBQ style food - on campus	break and travel time to banquet dinner	
6:00-6:30				
6:30-7:00				
7:00-7:30			Banquet Dinner at Battery Gardens 7-10 pm	

Keynote Speakers

Monday June 29th 2009
Prof. Dora Angelaki
Washington University
Melding of minds: Combination of sensory cues improves spatial perception

Tuesday, June 30th, 2009
Prof. Jon Kaas
Vanderbilt University
The organization of modules in posterior parietal cortex of primates for specific sensorimotor functions

Wednesday, July 1st, 2009
Prof. Nikos K. Logothetis
MPI for Biological Cybernetics
Multisensory Integration: Current Results and Future Methodologies

Symposium 1: Multisensory Processing in Flavor Perception

June 29th 2009

9:00 – 11:00

Organized by Garmt Dijksterhuis, Sensation, Perception & Behaviour Unilever R&D, The Netherlands and Andy Woods, Sensation, Perception & Behaviour, Unilever R&D, The Netherlands, and School of Psychology, University of Manchester, United Kingdom

Chair: Garmt Dijksterhuis

Speakers:

1. **Garmt Dijksterhuis**: Introduction

2. **Lawrence Marks**
   John B. Pierce Laboratory, Yale University School of Medicine
   Gustatory-Olfactory Integration in Human Flavor Perception

3. **Julie Boyle**
   McGill University
   Neural Correlates of Chemosensory Mixtures

4. **Donald Katz**
   Brandeis University
   The taste system modulates olfactory perception

5. **Massimiliano Zampini**
   University of Trento
   The role of auditory cues in the multisensory perception of foods and beverages

Symposium 2: New insights into crossmodal plasticity

June 29th 2009

5:00 – 7:00

Organized by Alex Meredith

Chair: Alex Meredith

Speakers:

1. **Susan Shore**
   Kresge Hearing Research Institute, University of Michigan Medical School
   Crossmodal Plasticity: not just for cortex any more

2. **Brian Allman**
   Virginia Commonwealth University
   Crossmodal Plasticity: not just for juveniles any more

3. **Steve Lomber**
   Centre for Brain and Mind, University of Western Ontario
   Crossmodal Plasticity: what is compensatory and what is not

4. **Gary Paige**
   University of Rochester
   Crossmodal Plasticity: not just sensory, but sensorimotor

Symposium 3: An embodied view of multisensory speech

June 30th 2009

10:30-12:30

Organised by Asif A Ghazanfar, *Princeton University*

Chair: Asif Ghazanfar

Speakers:

1. **Kevin Munhall**
   Queens University
   Temporal patterns in spoken language

2. **David Ostry**
   McGill University
   Somatosensory function in speech motor learning and perception

3. **Charlie Schroeder**
   Nathan Kline Institute & Columbia University
   Mechanisms and Significance of Multisensory Influences in Unisensory Cortices

4. **Asif A Ghazanfar**
   Princeton University
   Vocal communication through coupled oscillations

Symposium 4: Graduate student award talks

June 30th 2009

1:30 – 3:30

Awardees:

1. **Tamar R Makin**
   Neurobiology Department, Hebrew University of Jerusalem
   Amputees 'neglect' the space near their missing hand

2. **Catherine Perrodin**
   Max Planck Institute for Biological Cybernetics, Tubingen, Germany
   Visual influences on voice-selective neurons in the anterior superior-temporal plane

3. **Maria M Diehl**
   University of Rochester, School of Medicine and Dentistry, New York, USA
   Distinct temporal lobe projections to auditory and visual regions in the ventral prefrontal cortex support face and vocalization processing

4. **Talia Konkle**
   McGovern Institute for Brain Research & Department of Brain & CognitiveSciences, MIT, Massachusetts Institure of Technology, USA
   Motion aftereffects transfer between touch and vision

5. **Julie M Verhoff**
   Gallaudet University, Washington DC, USA
   Multisensory Integration in Prelingually Deafened Adults with Cochlear Implants

6. **Elena Azañón**
   Departament de Psicologia Bàsica, Universitat de Barcelona, Spain
   Disrupting spatial remapping of touch with TMS

7. **Ayla Barutchu**
   School of Psychological Science, La Trobe University, Melbourne, Australia
   The Development of Multisensory Facilitation in Children and Early Adolescence

Symposium 5: The Development of Multisensory Integration

July 1st 2009

10:30 – 12:30

Organised by David J. Lewkowicz, *Florida Atlantic University*

Co-Chairs: David J. Lewkowicz, *Florida Atlantic University and Mark Wallace, Vanderbilt University*

Speakers:

1. **Robert Lickliter & Lorraine Bahrick**
   Florida International University
   A Framework for the Development of Intersensory Perception: Four Predictions of the Intersensory Redundancy Hypothesis

2. **David J. Lewkowicz**
   Florida Atlantic University
   Narrowing of Intersensory Perception in Early Development

3. **Asif A. Ghazanfar**
   Princeton University
   Developmental timing and the evolutionary emergence of multisensorysystems in primates

4. **Mark Wallace**
   Vanderbilt University
   Development of Multisensory Cortical and Subcortical Representations

5. **Bruce D. McCandliss** (discussant)
   Vanderbilt University

Symposium 6: Plasticity and Synergy in Multisensory Integration

July 2nd 2009

2:00 – 4:00

Chair: Barry Edward Stein, *Wake Forest University School of Medicine*

Speakers:

1. **Barry Edward Stein**
   Wake Forest University School of Medicine
   Developmental Plasticity in the Cortical Control of Multisensory Integration in the Superior Colliculus

2. **Terrence R Stanford**
   Wake Forest University School of Medicine
   Multisensory Integration in the Superior Colliculus Requires Synergy among Cortical Inputs from Modality-Specific Subregions of the Anterior Ectosylvian Sulcus

3. **Benjamin Rowland**
   Wake Forest University School of Medicine
   Long-term Plasticity in SC Multisensory Integration: the Acquisition of Multisensory Integration Capabilities During Adulthood

4. **John G McHaffie**
   Wake Forest University School of Medicine
   Cross-modal Rehabilitative Training Ameliorates Visuomotor Deficits Produced by Visual Cortex Lesions

5. **Elisabetta Làdavas,**
   University of Bologna
   A Multisensory-based Approach to the Recovery of a Unisensory Deficit

Oral Session 1: Attention

June 29th 2009

3:00 – 4:30

Speakers:

1. **Marty G. Woldorff**
   Duke University
   Attentional influences on multisensory processing

2. **Thomas Koelewijn**
   Vrije Universiteit Amsterdam
   Competition for attentional resources between auditory and visual spatial cues

3. **Adele Diederich**
   Jacobs University Bremen
   Redundant target or focused attention: Two different paradigms but the same crossmodal integration mechanism

4. **Charles Spence**
   University of Oxford
   Explaining the Colavita Visual Dominance Effect

Oral Session 2: Body Schema

June 30th 2009

4:30 – 5:30

Speakers:

1. **Vanessa Harrar**
   Department of Psychology, Centre for Vision Research, York University, Toronto
   The effects of arm and eye position on the perceived location of touches on the arm

2. **Lucilla Cardinali**
   INSERM U864 "Espace et Action"
   Tool-use induces functional updating of the body schema

3. **Manos Tsakiris**
   Department of Psychology, Royal Holloway University of London
   Having a body versus moving your body: neural signatures of body-ownership and agency

Oral Session 3: Development

July 1st 2009

2:00 – 4:00

Speakers:

1. **Elena Nava**
   University of Trento
   The Illusory Flash Effect in *school-aged children* reveals developmental changes in auditory dominance

2. **John J Foxe**
   City College of New York
   The breakdown of multisensory speech perception in autism and schizophrenia

3. **Andrew J. Bremner**
   Goldsmiths, University of London
   The development of visual-proprioceptive integration in reaching in typically developing children and children with a diagnosis of Developmental Coordination Disorder (DCD)

4. **Annalisa Setti**
   Trinity College Institute of Neuroscience
   Audio-visual integration in fall-prone older adults

5. **Marko Nardini**
   Birkbeck College, University of London
   Development of variance reduction by cue integration between and within modalities

6. **Natalie Phillips**
   Concordia University
   Age differences in the pattern of benefit of audio-visual speech perception in younger and older adults

Oral Session 4: Modelling and brain mapping

July 2nd 2009

10:30 – 12:30

Speakers:

1. **Abdelhafid Zeghbib**
   Leibniz Institute for Neurobiology, Magdeburg, Germany
   Phase coherence evolution in cortical networks: adaptation to audiovisual stimulation with fixed inter-modality asynchrony

2. **Ellen C Haas**
   U.S. Army Research Laboratory
   Tactile and Auditory Cues to Communicate Multiple Levels of Information

3. **Jean Vroomen**
   Tilburg University
   Phonetic learning in audiovisual speech

4. **Uta Noppeney**
   Max Planck Institut for Biological Cybernetics
   Inverse effectiveness in BOLD-response and its behavioural relevance in object categorization

5. **Jan Theeuwes**
   Cognitive Psychology, Vrije Universiteit
   ERP Evidence for early cross-modal integration in visual selection

6. **Ladan Shams**
   UCLA
   Multisensory learning: from calibration, to associative learning to perceptual learning

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ORAL SESSIONS

Oral Session 5: Other

July 2nd 2009

4:30 – 6:00

Speakers:

1. **Rachel Denison**
   UCL Institute of Cognitive Neuroscience, University College London
   Sensitivity to audiovisual correspondence depends on temporal structure

2. **Cesare Valerio Parise**
   University of Oxford
   'When birds of a feather flock together': Synesthetic correspondences modulate audiovisual integration in non-synesthetes

3. **Sazzad M Nasir**
   Department of Psychology, McGill University
   Speech Motor Learning Modifies Speech Perception Psychophysics / Experimental Psychology

4. **Thorsten Kluss**
   Human Neurobiology, Bremen University; Cognitive Neuroinformatics, University of Bremen
   Influence of Visual Stimuli on Auditory Apparent Motion Perception

5. **David Alais**
   University of Sydney
   The number and precision of neural timing processes underlying duration perception in vision and audition, estimated using the "equivalent noise" paradigm

POSTERS I
June 29th 2009
11:00 – 12:30

1. **Lorraine E. Bahrick, James T. Todd, Melissa A. Argumosa, Rebecca Grossman, Irina Castellanos, Barbara M. Sorondo**
Intersensory Facilitation Across the Life-Span: Adults Show Enhanced Discrimination of Tempo in Bimodal vs. Unimodal Stimulation

2. **Zhuanghua Shi, Lihan Chen, Hermann J. Müller**
Auditory capture on the visual Ternus effect: the influence of subjective inter-sound interval

3. **Roy Hoshi**
Gone in a Flash: Manipulation of Audiovisual Temporal Integration Using Transcranial Magnetic Stimulation

4. **Jean Vroomen, Martijn Baart**
Phonetic recalibration only occurs in speech mode

5. **Anna Siever, Frank Bremmer**
The influence of auditory velocity cues on distance reproduction during simulated self motion

6. **Bruno Lucio Giordano, Federico Avanzini, Marcelo Wanderley, Stephen McAdams**
Integrating nonspatial, nontemporal multisensory information in action-based perception

7. **E. Courtenay Wilson, Louis D. Braida, Charlotte M. Reed** Perceptual Interactions in the Detectability and Loudness of Combined Auditory-Tactile Stimuli

8. **Hans Colonius, Adele Diederich**
The optimal time window of integration

9. **Jyrki Tuomainen, Raeya Abbas, Michael Coleman**
Audio-visual speech perception and attention

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10. **Pierre-Luc Gamache, Simon Grondin**
Modality-Specific Clock Components and Memory Mechanisms: Evidence from Parallel Timing

11. **Paula Plaza, Isabel Cuevas, Olivier Collignon, Cécile Grandin, Anne G DeVolder, Laurent Renier**
Perceiving schematic faces and man-made objects using a visual-to-auditory sensory substitution activates the fusiform gyrus

12. **Masaharu Kato, Norimichi Kitagawa, Makio Kashino**
Recalibration of perceptual timing between one's own action and associated sensory feedback

13. **Isabel Cuevas, Paula Plaza, Philippe Rombaux, Cécile Grandin, Olivier Collignon, Anne G. De Volder, Laurent Renier**
Olfactory processing in early blind subjects: psychophysical and functional magnetic resonance imaging study

14. **Laura S. Copeland, Shari R. Baum, Vincent L. Gracco**
Audiovisual integration of emotional and linguistic signals in voice and face

15. **Karin Petrini, Phil McAleer, Frank Pollick**
Audiovisual integration of emotional signals from solo improvisation

16. **Andy Thomas Woods, Ellen Poliakoff, Donna Lloyd, Garmt Dijksterhuis**
Perceptual constancy effects in taste discrimination

17. **Andrew J. Bremner, Francia Acosta-Saltos, Charles Spence, Jan de Fockert**
Effects of a secondary task and working memory load on visual-proprioceptive multisensory integration when reaching

18. **Malika Auvray, Alberto Gallace, Charles Spence**
Short term memory for tactile stimuli presented on the fingertips and across the body surface

POSTERS

19. **Tanja Kassuba, Corinna Klinge, Cordula Hagemann, Hartwig R. Siebner**
The left fusiform gyrus processes visual, tactile, and auditory features of manipulable objects

20. **Lisa Dopjans, Christian Wallraven, Heinrich H. Bülthoff**
Visual experience supports haptic face recognition: Evidence from the early- and late-blind

21. **Yoshinori Tanizawa, William R. Schafer**
Multisensory processing and arousal modulation in the nematode C. elegans

22. **Maori Kobayashi, Shuichi Sakamoto, Yoiti Suzuki**
Audio-visual synchrony perception for stimulus onset and offset

23. **Kaleb McDowell, W. David Hairston, Ellen Haas, Kelvin S Oie**
From bench to battlefield: Translating multi-modality research to system design

24. **Nadia Bolognini, Costanza Papagno, Angelo Maravita**
Tactile Temporal Processing in the Auditory Cortex

25. **Olivier Collignon, Geneviève Charbonneau, Maryse Lassonde, Franco Lepore**
Early visual deprivation alters multisensory processing in peripersonal space

26. **Axel H Winneke, Natalie A Phillips**
Young and old process audiovisual speech more efficiently than auditory speech: an erp study of audiovisual speech in noise

27. **Victoria Cheah, Jarmo Hamalainen, Fruzsina Soltesz, Usha Goswami**
Do Dynamic Visual Analogues Aid Detection of Auditory Stress Patterns in Dyslexia?

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POSTERS

28. **Richard Kirk Lewis, Uta Noppeney**
Visual-Auditory Synchrony Boosts BOLD Response in Posterior Temporal and Occipital Cortices

29. **Hsin-Ni Ho, Junji Watanabe, Hideyuki Ando, Makio Kashino**
Thermal intensity perception under thermo-tactile interaction

30. **Maria Mittag, Rika Takegata, Teija Kujala**
The effects of temporal synchrony and visual material on audio-visual integration

31. **Neil Roach, James Heron, David Whitaker, Paul McGraw**
Asynchrony adaptation induces non-uniform changes in perceived timing

32. **Joanna Edel McHugh, Fiona N Newell**
Mixed Emotions: Audition can modulate the visual perception of the emotion of a crowd

33. **Zhuanghua Shi, Lihan Chen, Hermann J. Müller**
Auditory capture on the visual Ternus effect: the influence of subjective inter-sound interval

34. **Dan Zhang, Bo Hong, Brigitte Röder, Shangkai Gao**
Auditory Stimuli Induce a Desynchronization of Steady-state Visual Evoked Potentials

35. **Yoshimori Sugano, Mirjam Keetels, Jean Vroomen**
Visuo-Motor versus Audio-Motor Temporal Recalibration

36. **Verena Conrad, Andreas Bartels, Mario Kleiner, Uta Noppeney**
Auditory influences on the temporal dynamics of binocular rivalry

37. **Frederic Joassin, Pierre Maurage, Mauro Pesenti, Emilie Verreckt, Raymond Bruyer, Salvatore Campanella**
The cerebral network involved in the cross-modal interactions between human faces and voices during recognition

38. **Flavia Cardini, Marcello Costantini, Gaspare Galati, Elisabetta Làdavas, Andrea Serino**
Neural modulation of felt and seen touch on one's own face: a fMRI study

39. **Filipa Campos Viola, Jemma Hine, Jeremy Thorne, Angela Barks, Julie Eyles, Stefan Bleck, Till Schneider, Stefan Debener**
Visual take-over in postlingually deafened adult cochlear implant users

40. **Michael Joseph Banissy, Vincent Walsh, Jamie Ward**
Enhanced Sensory Perception in Synaesthesia

41. **Johannes Frasnelli**
Olfactory function is correlated to cortical thickness of chemosensory and non-chemosensory regions

42. **Benjamin Taylor Files, Lynne E Bernstein**
Neural correlates of disambiguating an ambiguous multisensory motion stimulus

43. **Sascha Tyll, Bjoern Bonath, Hans-Jochen Heinze, Toemme Noesselt**
Temporal dynamics of sound-induced contrast enhancement

44. **Elisa Magosso, Andrea Serino, Mauro Ursino, Cristiano Cuppini, Giuseppe Di Pellegrino Elizabetta Làdavas**
Neural correlates of peri-hand space re-sizing following tool use: A combined computational and in vivo study

45. **Flavia Mancini, Emanuela Bricolo, Giuseppe Vallar**
A Crossmodal Müller-Lyer Illusion

46. **Nina Jahn, Kielan Yarrow**
In search of an efferent rule in multisensory binding

47. **Pascale Touzalin-Chretien, André Dufour**
Cortical motor activity modulated by vision of the hand

48. **M. Alex Meredith, Leslie P Keniston, Brian L Allman**
Areal heterogeneity of bimodal neurons

49. **Natalie Russo, John J Foxe, Hilary Gomes, Alice Brown, Ted Altschuler, Sophie Molholm**
Multisensory processing in children with autism: high-density electrical mapping of auditory-somatosensory integration

50. **Ian C. Fiebelkorn, John J Foxe, Adam Snyder, Daniella Blanco, Theodore Schwartz, Sophie Molholm**
Multisensory Feature Integration: Does Pre-attentive Visual Object Processing Modulate the Cross-Sensory Spread of Attention?

POSTERS II
June 30th 2009
9:00 – 10:30

51. **Mary Kim Ngo, Charles Spence**
Evaluating the Effectiveness of Temporally Synchronous and Spatially Predictive Cues in Visual Search

52. **Sarah E. Donohue, Maria A. Pavlova, Kenneth C. Roberts, Tineke Grent-'t Jong, Marty G. Woldorff**
Multisensory attentional-spread activity reveals tighter audiovisual-synchrony constraints for the spatial shifts of ventriloquism than for the temporal linking of auditory and visual events

53. **Jordi Navarra, Jessica Hartcher-O'Brien, Charles Spence**
Adaptation to audiovisual asynchrony modulates the speeded detection of Sound

54. **Jason S Chan, Simon Dobbyn, Paul McDonald, Henry J Rice, Carol O'Sullivan,Fiona N Newell**
Aurally aided visual search in depth using 'real' and 'virtual' crowds

55. **Jeroen Stekelenburg, Jean Vroomen**
Audiovisual speech integration is modulated by the interpretation of the auditory stimuli: An ERP study

56. **Jenelle Hall, Simon Lacey, K Sathian**
Surface properties affect within- and cross-modal object recognition

57. **Tomoko Yonemura, Hiroki Kawasaki, Shin Okamoto, Hideyuki Ando, Taro Maeda**
A relation between Pseudo-Haptic perception and preceding / delayed visual image

58. **Yixuan Ku, Wenjing Zhou, Dan Zhang, Bo Hong, Xiaorong Gao, Shangkai Gao,**
Amodal central calculation system underlying visual and auditory expert adding performance: a case study

59. **Norimichi Kitagawa, Masaharu Kato, Makio Kashino**
Assessing the effects of voluntary action on sensitivity to temporal asynchrony between auditory and somatosensory events

60. **Souta Hidaka, Wataru Teramoto, Jiro Gyoba, Yôiti Suzuki**
Effects of tone-sequence frequency changes on visible persistence of apparently moving visual stimuli

61. **Rob Henricus van der lubbe, Jurjen van der Helden**
The timing of supramodal and unimodal spatial selection in a trial-by-trial cuing paradigm

62. **Antje Fillbrandt, Frank W Ohl**
Audiovisual category transfer in rodents

63. **Krista Overvliet, Elena Azañon, Salvador Soto-Faraco**
Saccade characteristics reveal the timing of somatosensory encoding

64. **Victoria Cheah, Fruzsina Soltesz, Denes Szucs, Usha Goswami**
Auditory-Visual Interactions and Rhythmic Structure

65. **Philip Jaekl, Salvador Soto-Faraco**
A Comparison of Audio-Visual Interactions in Magno- and Parvocellular Visual Pathways

66. **Akihiro Tanaka, Ai Koizumi, Hisato Imai, Saori Hiramatsu, Eriko Hiramoto, Beatrice de Gelder**
Perception of emotion in face and voice: Crosscultural comparison

67. **James Heron, James Vincent Michael Hanson, David Whitaker**
Effect before cause: sensorimotor temporal recalibration across the senses

68. **Marco Calabresi, Alfonso Barrós-Loscertales, Noelia Ventura-Campos, Juan Carlos Bustamante, Agnés Alsius, César Avila, Salvador Soto-Faraco**
Neural correlates of audiovisual speech integration in second language

69. **W. David Hairston, Tomasz R Letowski, Kaleb McDowell**
Examining cross-modal influence of the auditory brainstem response

70. **Celine Cappe, Gregor Thut, Vincenzo Romei, Micah M. Murray**
Auditory-visual multisensory interactions between task-irrelevant stimuli engage distinct configurations of brain networks at early latencies in humans

71. **Chandramouli Chandrasekaran, Asif A Ghazanfar**
Different Neural Frequency Bands Integrate Faces and Voices Differently in the Superior Temporal Sulcus

72. **Julia Föcker, Brigitte Röder**
Audio-visual integration of emotional processing: Evidence from event-related potentials

73. Jeremy Thorne, Filipa Campos Viola, Till Schneider, Stefan Debener
Facilitation and Interference Effects in Crossmodal Semantic Priming

74. Georg F Meyer, Sophie Wuerger
Evidence for distinct roles of posterior superior temporal sulcus and inferior frontalareas in audiovisual action recognition

75. Nina Gaißert, Christian Wallraven, Isabelle Bülthoff
From unsupervised to supervised categorization in vision and haptics

76. James Philip Thomas, Maggie Shiffrar
Veridical auditory information enhances visual sensitivity to biological motion

77. Michelle L. Cadieux, Michael Barnett-Cowan, David I. Shore
Gender and Vision in the Crossed Hands TOJ Deficit

78. Andrea Serino, Elisabetta Làdavas, Alessio Avenanti
Fronto-parietal areas necessary for a multisensory representation of the Peripersonal Space in humans: a r-TMS study

79. Hwee-Ling Lee, Uta Noppeney
Audiovisual synchrony detection for speech and music signals

80. Nienke van Atteveldt, Alard Roebroeck, Rainer Goebel
Granger causality mapping reveals congruency-dependent directed influences fromsuperior temporal to auditory cortex during audiovisual integration

81. H Ruth Clemo, M. Alex Meredith
Crossmodal corticocortical projections preferentially terminate in supragranular laminae

82. DaeGee KANG, Ryota MIYAUCHI, Yukio IWAYA, Yo-iti SUZUKI
Spatial integration of audio-visual infromation in the peripheral visual field

83. Yousuke Kawachi, Michiaki Shibata, Hideaki Kawabata, Miho Kitamura, Jiro Gyoba
The critical pre/post-event temporal range for stable crossmodal perception: Evidence from the stream/bounce display

84. Cristiano Cuppini, Mauro Ursino, Elisa Magosso, Benjamin Rowland, Barry Stein
Multisensory integration in superior colliculus (SC) neurons: a computational study

85. Claudia Passamonti, Fabrizio Leo, Elisabetta Làdavas
The impact of Multisensory and Unisensory Integration on covert and overt orienting

86. Valeria Occelli, Helge Gillmeister, Bettina Forster, Jess Hartcher O'Brien, Charles Spence, Massimiliano Zampini
Behavioural investigations of audiotactile interactions in humans

87. Su-Ling Yeh, Yung-Hao Yang
Unmasking the dichoptic mask by sound

88. Ana Catarina Mendonça, Jorge A Santos, Miguel Castelo-Branco
Does Maximum Likelihood Integration Predict How we Perceive Walking Humans? A Study on the Audiovisual Integration of Biological Motion

89. Carolina Sanchez, Agnès Alsius, James T Enns, Salvador Soto-Faraco
Crossmodal prediction during perception of audiovisual speech

90. Laurent Albert Renier, Irina Anurova, Anne Ghislaine De Volder, Synnöve Carlson, John VanMeter, Josef Peter Rauschecker
Multi-modal versus modality-specific activation within the "what" and "where" processing streams for sounds and vibro-tactile stimuli

91. Isadora Olive, Julien Barra, Alain Berthoz
Turning the body inside-out: localization of force feedback beyond bodily boundaries induced by multisensory visuo-tactile conflict

92. Davide Bottari, Anne Caclin, Marie-Hélène Giard, Francesco Pavani
Modulations of early visual evoked potential in the profoundly deaf

93. Paul J Laurienti, Christina E Hugenschmidt, Joseph A Maldjian, Benjamin Wagner, Satoru Hayasaka
Network Analyses of Multisensory Processing

94. Jennifer L. Campos, John S. Butler, Heinrich Bülthoff
Visual-Vestibular Cue Combination during Temporal Asynchrony

95. Joshua N Lucan, John J Foxe, Sophie Molholm
A helping hand: an enhancement of the visual response by skin region

96. Anne-Sylvie Crisinel, Charles Spence
Assessing the implicit association between sour food & high-pitched sounds

97. Martine Godfroy, Joel Miller, Patrick MB Sandor, Bernard D. Adelstein
Visual Orientation and Navigation in 3D space: Active manual controlcountermeasures

98. Malika Auvray, Thomas Hoellinger, Sylvain Hanneton, Agnes Roby-Brami
Perceptual weight judgments when viewing own and other's movements under minimalist conditions of visual presentation

99. Brian L Allman, Leslie P Keniston, M. Alex Meredith
The "Continuum Hypothesis": Different patterns of multisensory convergence generate a range of multisensory neurons

POSTERS III
July 1st 2009
9:00 – 10:30

100. Shinya Yamamoto, Makoto Miyazaki, Takayuki Iwano, Shigeru Kitazawa
Two opposing mechanisms in the calibration of simultaneity in temporal order Judgments

101. Monica Gori, Allessandra Sciutti ,Giulio Sandini, David Burr
Multimodal Bayesian combination of visual information about object size with observation of an actor: cue integration by the mirror neuron system?

102. Georgiana Juravle, Heiner Deubel, Charles Spence
What you feel within a move: The spread of tactile attention during goal directed movements

103. Anna Seemüller, Katja Fiehler, Frank Rösler
Crossmodal short-term memory representation of visual and kinaesthetic information

104. Brian L Allman, Leslie P Keniston, M. Alex Meredith
Massive crossmodal reorganization of ferret auditory cortex induced by adult-deafness

105. Carmel A Levitan, Megumi Sugawara, Charles Spence
Does color have a perceptual and/or cognitive (decisional) influence on human flavor perception?

106. Cristina Simoes-Franklin, Mark Byrne, T. Aisling Whitaker, Fiona N. Newell
Do effects of training on texture categorisation transfer across modalities?

107. Bjoern Bonath, Sascha Tyll, Hans Jochen Heinze, Steven A. Hillyard, Toemme Noesselt
Spatial and temporal factors in audiovisual interplay: An fMRI sudy

108. Shuichi Sakamoto, Fumimasa Furune, Wataru Teramoto, Kenzo Sakurai, Jiro Gyoba, Yo-iti Suzuki
Effect of vestibular information on sound source distance travelled estimation

109. Ilja Frissen, Mounia Ziat, Gianni Campion, Vincent Hayward, Catherine Guastavino
Auditory-tactile temporal order judgments during active exploration

110. Daniel Rogers, Simon Dobbyn, Paul McDonald, Henry J. Rice, Carol O'Sullivan, Fiona N. Newell
Does sound help locate a moving visual target in a busy dynamic scene?

111. Kasper Eskelund, Tobias S Andersen
Specialization in audiovisual speech perception: a replication study

112. Eike Budinger, Henning Scheich
Anatomical connections suitable for the direct processing of multimodal information via the rodent primary auditory cortex

113. Ignacio Velasco Marugán, Jordi Navarra
Is audiotactile temporal recalibration stimulus-specific?

114. Francesco Campanella, Maria Concetta Morrone, Giulio Sandini
Visual object recognition by prehension movement

115. Sandra Quinn, David Burr
The perception of temporal regularity across modalities

116. Sebastian Werner, Uta Noppeney
The contributions of transient and sustained responses to audio visual integration of dynamic information

117. Jennifer Lynn Woodland, Alexander E. Wilson
An investigation of visuohaptic integration: visual vs. haptic dominance; unimodal vs. bimodal exploration; common vs. uncommon sources

118. Yoshinao Kajikawa, Charles E Schroeder
Enhancement of vocal sound detection by facial view in the monkey

119. Nick Altieri, Noah Silbert, Lei Pei
An Investigation of Perceptual Dependencies in Audiovisual Speech Perception

120. Joji Tsunada, Allison E Baker, Selina J Davis, Asif A Ghazanfar, Yale E Cohen
Vocalization-context dependent neural representation of faces in monkey lateral prefrontal cortex

121. Ryan Andrew Stevenson, Sunah Kim, Thomas Wellington James
Investigating viable criteria for assessing neuronal convergence with BOLD fMRI

122. **Paul Ryan MacNeilage, Jimmy Zhang, Dora Angelaki**
Vestibular facilitation of optic flow parsing

123. **Juliane Krueger, Matthew C Fister, Michelle S Young, Zachary P Barnett, Brian N Carriere, David W Royal, Mark T Wallace**
A Comparison of Spatial Receptive Field Architecture of Multisensory Neurons in Subcortex and Cortex

124. **Ewen A. Chao, Bosco S. Tjan, Lynne E. Bernstein**
A Visual or Tactile Signal Can Make the Auditory System More Efficient but Not Less Noisy

125. **Vivian M. Ciaramitaro, Karen R. Dobkins**
Auditory influences on attending to and processing low-level visual stimuli early in development

126. **Ana Tajadura-Jiménez, Manos Tsakiris**
I'll be your mirror: Visuo-tactile stimulation modulates the representation of one's own face

127. **Michael Barnett-Cowan, Laurence R Harris**
Vestibular perception is slow

128. **Melissa M Pangelinan, Erika K Hussey, Shelby N Wilson, David E Poeppel**
Decomposition of audiovisual interactions in event-related fields using independent component analysis

129. **Wataru Teramoto, Souta Hidaka, Jiro Gyoba, Yo-iti Suzuki**
Completion of a visual motion representation by auditory information

130. **Beatriz Blanca, Daniel Sanabria, Jordi Navarra, Ángel Correa**
Pay attention, the message is coming up!

131. **Jintao Jiang**
Integration of Cued Speech with residual hearing

132. **Jean M Vettel, Adrian Nestor, Chris W. Bird, Laurie M. Heller, Tim Curran, Michael J. Tarr**
Investigating the Interplay of Time & Semantics during Multimodal Integration

133. **Kohske Takahashi, Katsumi Watanabe**
Distortion of visual and auditory duration in short term memory

134. **Uri Hertz, Amir Amedi**
Brain topography and the binding problem at the multisensory level in humans: new insights gained by using fMRI spectral analysis

135. **Noa Tal, Amir Amedi**
A visuo-haptic object-related fMR-adaptation: a new approach to studying multisensory interactions

136. **Sunah Kim, Daniel Eylath, Ryan Stevenson, Aaron Scott, Thomas James**
Inverse effectiveness in the left but not right lateral occipital cortex during visuo-haptic object categorization

137. **Ulrike Zimmer, Suksun Itthipanyanan, Marty G Woldorff**
Does a task-irrelevant sound modulate the spread of visual attention differently in lateral versus central visual attention?

138. **Jan L. Souman, Verena Eikmeier, Marc O. Ernst, Tom C.A. Freeman**
Walking changes perceived visual speed of both expanding and contracting optic flow fields

139. **Andrea R. Hillock, Albert R. Powers, Mark T. Wallace**
Maturation of audiovisual simultaneity judgment

140. **Su-Ling Yeh, Chien-Hui Chiu, Chuan-Heng Hsiao**
Cross-modal attention in the pause-and-go fan illusion

141. **Anca Melania Stratulat, Christophe Bourdin, Vincent Roussarie,**
Jean-Louis Vercher
Perception of deceleration during simulated steering by using variation of linear acceleration and tilt.

142. **Yuji Wada, Nobu Shirai, Yumiko Otsuka, So Kanazawa, Masami K Yamaguchi**
Visual freezing effect by sound in infants

143. **Yuki Miyazaki, Takako Yoshida, Hiromi Wake, Tenji Wake, Shigeru Ichihara**
Short-term Memory Representation of Tactile Stimuli to Fingertips

144. **John S. Butler, Jennifer L. Campos, Heinrich H. Bülthoff, Stuart T Smith**
Bayesian integration of visual and vestibular signals for heading

145. **T Aisling Whitaker, Cristina Simoes-Franklin, Fiona N Newell**
Elucidating the correlates of the multisensory perception of naturalness

146. **Brigitte Röder, Maren Wolfram, Nils Skotara, Julia Föcker**
Affective expression as multisensory binding feature in a ventriloquist situation

147. **Malika Auvray, Charles Spence**
What perspective do people take when interpreting tactile letters presented on their bodies?

148. **Mirjam Keetels, Jean Vroomen**
Auditory Effects on the Timing of Exogenous and Endogenous Visual Attention

POSTERS IV
July 2nd 2009
9:00 – 10:30

149. **Jasper J.F. van den Bosch, Yavor Yalachkov, Oliver Doehrmann, Jochen Kaiser, Marcus J. Naumer**
Effective connectivity of human lateral occipital complex (LOC) during visuo-haptic object perception

150. **Clara Aranda, Maria Ruz, Daniel Sanabria, Manos Tsakiris, Pio Tudela**
Orienting endogenous attention to our own and other's body representations

151. **Marcus J. Naumer, Jasper van den Bosch, Michael Wibral, Axel Kohler, Wolf Singer, Jochen Kaiser, Vincent van de Ven, Lars Muckli**
Combining hypothesis-generating and hypothesis-testing tools during analyses of multisensory fMRI data

152. **Leslie P Keniston, Brian L Allman, M. Alex Meredith**
Temporal influence on bimodal multisensory processing in the lateral rostral suprasylvian sulcus (lrss) of the ferret

153. **Zhi Li, Frank H Durgin**
Proprioceptive mis-estimation of head orientation and the apparent steepness of downhill slopes

154. **I-Fan Lin, Barbara G. Shinn-Cunningham**
Audio-visual interactions in discrimination of intensity changes

155. **Beatriz R. Sarmiento, Daniel Sanabria Lucena**
Audiovisual interaction: Spatial attention effects and duration illusion

156. **Huiyang Li, Thomas Ferris, Nadine Sarter**
The Semantics of Touch: How People Intuitively Perceive and Interpret Tactile Signals

157. **Robyn Sun Kim, Aaron Seitz, Ladan Shams**
Statistical learning of crossmodal associations is better than unisensory associations

158. **Albert R. Powers, Andrea R. Hillock, Mark T. Wallace**
Multiple Modes of Perceptual Training Induce a Narrowing in the Multisensory Temporal Binding Window

159. **Kensuke Oshima, Shigeru Ichihara**
The way of touch: the important factor for visual adjustment of haptic size judgements

160. **M. Gomez-Ramirez, C. Lee, J. F. Dammann III, J. C. Craig, S. S. Hsiao, T. Yoshioka**
Interactions between tactile and auditory signals in roughness perception: A human psychophysical study

161. **Xiang Zhou, Wei Ji Ma, Lars A Ross, John J Foxe, Lucas C Parra**
Lip-reading aids word recognition most in moderate noise: a Bayesian explanation using high-dimensional feature space

162. **Adria E. N. Hoover, Laurence R. Harris, Jennifer K. E. Steeves**
The effect of binocular and monocular viewing on sound localization

163. **Leslie Ellen Dowell, Haleh Kadivar, Mark Wallace**
Unisensory temporal performance is predictive of the size of the temporal window of multisensory integration

164. **Oliver Alan Kannape, Tej Tadi, Olaf Blanke**
Body orientation and perspective influence conscious monitoring of locomotion in a virtual reality setting

165. **Matthias Bischoff, Knut Drewing, Tobias Polley, Carlo Blecker, Karen Zentgraf, Dieter Vaitl, Gebhard Sammer**
fMRI of a visual-haptic ambiguous rotating sphere

10th International Multisensory Research Forum

166. **Gabriella Musacchia, Peter Lakatos, Aimee Mills, Charles Schroeder**
Auditory input modulates activity in primary somatosensory cortex

167. **Ella Striem, Ornella Dakwar, Amir Amedi**
Highly transient neuroplasticity following one session of learning to use a sensory substitution device: an fMRI study

168. **Claudio Brozzoli, Romeo Salemme, Alessandro Farnè**
You see? You dont' feel: Spatially Modulated Visuo-tactile Extinction in Healthy Subjects

169. **Durk Talsma**
Low but accurate detection rates for small degrees of Audiovisual Asynchrony

170. **Christopher R. Fetsch, Amanda H. Turner, Gregory C. DeAngelis, Dora E. Angelaki**
Reliability-based cue re-weighting in rhesus monkeys: behavior and neural correlates

171. **Joanna M. Koutros, Brian T. Quinn, Chad Carlson, Amy Trongnetrpunya, Eric Halgren, Thomas Thesen**
Tactile Influence Upon Visual Perception of the Ambiguous Motion Quartets

172. **Lars Torben Boenke, Matthias Deliano, Frank Ohl**
Stimulus duration has influence on the perceived simultaneity in audiovisual temporal order judgment

173. **Kate Burke, Annalisa Setti, Marco T. Liuzza, Anna M. Borghi, Fiona N. Newell**
Visuo-motor resonance in older adults

174. **Lisa Wise**
Cognitive load during training facilitates expert skilled performance in a complex spatio-temporal domain

POSTERS

175. Monica Gori, Giulio Sandini, Cristina Martinoli, David Burr
Haptic discrimination in blind and low-vision children

176. Rebecca Kate Reed, Edward T Auer, Jr
Multisensory influence on the perception of foreign accented speech

177. Valeria Ivanova Petkova, Henrik Ehrsson
When right feels left: referral of touch and ownership between the hands

178. Martine Godfroy, Robert Welch, Patrick MB Sandor, Corinne Roumes
Accuracy and Precision of Auditory-Visual Localization in the Two-Dimensional Frontal Field: A Test of the Modality Precision Model

179. Mark E McCourt, Yamaya Sosa, Aaron M Clarke
Hemifield Asymmetry in the Integration of Exogenous Auditory and Visual Cues in the Capture of Visuospatial Attention in Visual Line Bisection

180. Cliff Saron, Margarita Beransky, Yukari Takarae, David Horton, Ashley Stark, Susan Rivera
Sight, sound and touch less bound: a behavioral and ERP investigation of
multisensory integration deficits in children with autism spectrum disorders

181. Edyta Monika Hunter, Prof Louise H Phillips, Dr Sarah E MacPherson
Effects of Age on Multisensory Integration and Social Interaction

182. Annerose Engel, Peter E. Keller
Audiomotor interactions during listening to improvised piano melodies

183. Robert Whelan, Hugh Nolan, John S. Butler, Richard B. Reilly, Heinrich H. Bülthoff
The acquisition of Human EEG Data during Self-Motion on a Stewart Platform

184. Yi-Chuan Chen, Charles Spence
When hearing the bark helps to identify the dog: Semantically-congruent sounds modulate the identification of masked pictures

185. Cristy Ho, Charles Spence
Capturing driver attention by activating the brain's defensive system

186. Hugh Hawthorne, Andrew J. Bremner, Charles Spence
Eye gaze and head orientation as spatial cues to visual and auditory targets: The head's wired for sound

187. Yong Gu, Gregory C DeAngelis, Dora E Angelaki
Contribution of visual and vestibular signals in extrastriate visual cortex to heading perception

188. Julien Besle, Peter Lakatos, Cathy Schevon, Robert R Goodman, Guy McKhann, Ashesh D Mehta, Ron G Emerson, Charles E Schroeder
Entrainment of Neuronal oscillations as a mechanism of attentional selection: human intracranial recordings

189. David Wozny, Ulrik Beierholm, Ladan Shams
Ventriloquist aftereffect reflects a shift in auditory likelihood functions

190. Holger Franz Sperdin, Céline Cappe, Micah M Murray
Top-down influences on the detection and discrimination of spatially-distributed auditory-somatosensory events.

191. Christoph Kayser, Christoph Dahl, Stefano Panzeri, Nikos K Logothetis
Multisensory influences in auditory and superior temporal cortex

192. **Noriaki Kanayama, Masahiro Matsunaga, Hideki Ohira**
Polymorphism of the mu-opioid receptor gene (OPRM1) and visuotactile congruency effect

193. **Caterina Bertini, Claudia Passamonti, Benjamin Rowland, Barry Stein**
Multisensory disambiguation of a temporal pattern

194. **Toshiko Mochizuki, Rie Kashiwabara, Keiko Omori**
The ability of haptics to modulate the Ebbinghaus illusion

195. **Celine Cappe, Micah M. Murray**
Multisensory interactions facilitate categorical discrimination of objects

196. **José Van Velzen, Leola Thomas-Chirnside**
Effects of preparing a manual movement towards and away from the body on visual and tactile probe detection

197. **Toshio Kubodera, Philip M. Grove, Shuichi Sakamoto, Yo-iti Suzuki, Kenzo Sakurai**
Multimodal integration in perceiving direction of self-motion from visual and vestibular stimulation

198. **Tej Tadi, Patrick Salamin, Frederic Vexo, Olaf Blanke**
A Matter of Perspective: Exposure to third- as opposed to first-person perspective during walking enlargens peripersonal space

199. **Karin Petrini, Phil McAleer, Frank Pollick**
Audiovisual integration of emotional signals from solo improvisation

Day One

Monday June 29th 2009

8:30 –9:00	**Registration – open all day**
9:00 –11:00	**Symposium 1: Multisensory Processing in Flavor Perception** **Chaired by Garmt Dijksterhuis**
11:00 –12:30	**Posters I (coffee/snack)**
12:30 –2:00	**Lunch – buffet style at quad**
2:00 –3:00	**Keynote I – Dora Angelaki**
3:00 -4:30	**Oral Session 1: Attention**
4:30 –5:00	**Coffee/snack break**
5:00 –7:00	**Symposium 2: New Insights into crossmodal plasticity –** **Chaired by Alex Meredith**

Symposium 1 : Multisensory Processing in Flavor Perception

9:00 – 11:00

Chair: Garmt Dijksterhuis

Speakers:
Garmt Dijksterhuis: Introduction
Larry Marks, *John B. Pierce Lab. /Y ale University School of Medicine*

Julie Boyle, *Montreal Neurological Institute and Department of Psychology McGill University*

Donald Katz, *Department of Psychology Brandeis University*

Massimiliano Zampini, *Department of Cognitive Sciences and Education & Center for Mind/Brain Sciences, University of Trento*

Overview:
Flavour is defined as a multisensory percept (aroma and taste, sometimes including mouthfeel). In recent years, the role of multisensory integration in flavour has been has been slowly gaining interest and is probably now on the verge of snowballing. Virtually all sense systems are active during eating, so there will remain very much to do in this field and steps are being made to integrate emerging behavioural, neurophysiological and neuroimaging findings.
The first speaker, Larry Marks, will discuss his recent psychophysical work on additive mechanisms of gustatory and olfactory signals in the perception of flavour intensity. The second speaker, Julie Boyle, will discuss recent neuroimaging findings on the integration of olfactory, taste and trigeminal mixtures. The next speaker, Don Katz, will demonstrate that the arrow connecting taste and olfaction points both ways, demonstrating that olfactory perception is altered in a state-dependent manner by TASTE cortex inactivation. We will conclude by a presentation from the fourth speaker, Massimiliano Zampini, who will discuss the profound impact that auditory cues can have on our multisensory food perception.

10th International Multisensory Research Forum

Symposium 1 : Multisensory Processing in Flavor Perception

Gustatory-Olfactory Integration in Human Flavor Perception

Larry Marks

John B. Pierce Laboratory and Yale University School of Medicine

Human flavor perception involves the integration of sensory signals arising from gustation, olfaction, and somatosensation. Research in my laboratory has focused on interaction between gustatory and olfactory components of flavorants in the perception of flavor intensity. Measures of intensity processing include (a) detection of weak flavorants using forced-choice methods, (b) speed of response to detect stronger flavorants, and (c) ratings of flavor intensity of both perithreshold and suprathreshold flavorants. Results obtained from all three paradigms are consistent with the hypothesis that that flavor-intensity signals arising in the gustatory and olfactory channels add linearly. For the most part, changes in stimulus context appear to influence the signals in each channel independently.

DAY 1 - MONDAY

Symposium 1 : Multisensory Processing in Flavor Perception

Neural Correlates of Chemosensory Mixtures

Julie Boyle

Montreal Neurological Institute and Department of Psychology
McGill University

In their daily life, humans rarely encounter single odorants. More normally, complex mixtures of odorants and trigeminal sensations sum up to create a single odor-percept (i.e. the gestalt). Our lab is interested in regions of the human brain involved in the integration of these intricate chemosensory mixtures. Our research on binary and ternary odor mixtures has revealed functional specialization in two olfactory regions; the anterior and lateral orbitofrontal cortex (OFC). While the lateral portion of the OFC responds to mixture impurity in a graded fashion, the anterior portion acts as an on-off detector for the presence of mixtures of odorants. More recently, we have shown activation of the lateral OFC in response to odor/ trigeminal and taste mixtures, suggesting that this region may represent a more generalized chemosensory integration center.

10th International Multisensory Research Forum

Symposium 1 : Multisensory Processing in Flavor Perception

The taste system modulates olfactory perception

Donald Katz

Department of Psychology Brandeis University

"Flavor" appears to the perceiver to be primarily driven by taste, but is described by researchers as primarily reflecting smell; that is, the flavor percept emerges because activity of the olfactory system influences the taste system. Here, we demonstrate that the interaction of taste and smell is bi-directional--that the taste system is in fact necessary for normal olfaction. We trained rats to prefer a food by pairing the smell of that food with the smell of a conspecific's breath (this learning is called Social Transmission of Food Preference, or STFP). STFP was acquired purely on the basis of the olfactory cues present during the training interaction, but both acquisition and expression of the learning could be inhibited by inactivation of gustatory cortex (GC) via intra-cranial infusions of the GABA-A agonist muscimol. This effect represented a true case of state-dependency: when we inactivated GC in either training or testing sessions, no preference was learned; when we inactivated GC in both sessions, however, normal performance is rescued. We conclude that cortical inactivation does not make it impossible to form flavor percepts, but rather significantly alters flavor percepts. Thus, it makes no more sense to think about olfaction in isolation from gustation than it does to think about gustation in isolation from olfaction.

DAY 1 - MONDAY

Symposium 1 : Multisensory Processing in Flavor Perception

The sound of food: The role of auditory cues in the multisensory perception of foods and beverages

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Our perception of the food we eat is derived from the integration of multisensory cues. Not only is it important what a food looks, smells and tastes like, but also what it feels like (i.e., oral texture) and sounds like in the mouth. Auditory cues play an important role in people's evaluation of food and drink, especially their perception of the crispness of dry food products or of the level of carbonation in beverages. In a series of study, we have demonstrated that the modulation of high frequency components (2–20 kHz) and/or of the overall loudness of the sounds produced by foods can influence our perception of them. In particular, we have shown that the perception of the crispness and staleness of potato chips can be affected by modifying the sounds produced during the biting action. In a follow-up study, we have also found that the perception of carbonation in beverages can be influenced by varying the water sounds. Taken together, these results highlight the significant role that auditory cues can play in modulating the perception and evaluation of foodstuffs (despite the fact that we are often unaware of the influence of such auditory cues).

POSTERS I
June 29th 2009
11:00 – 12:30

Intersensory Facilitation Across the Life-Span: Adults Show Enhanced Discrimination of Tempo in Bimodal vs. Unimodal Stimulation

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According to the Intersensory Redundancy Hypothesis (IRH; e.g., Bahrick & Lickliter, 2000, 2002), perceptual processing of amodal properties (e.g., tempo, rhythm, intensity) is facilitated in bimodal, redundant stimulation (intersensory facilitation) and attenuated in unimodal, nonredundant stimulation. Thus far, research supporting this hypothesis has primarily focused on infancy. However, we predict that intersensory facilitation extends across the life span, particularly for tasks of high difficulty or cognitive load. Preliminary support for this hypothesis comes from a study of infants' discrimination of tempo change. Younger infants showed intersensory facilitation for easy tasks, but older infants showed intersensory facilitation only for more difficult tasks (Bahrick, Lickliter, Castellanos, & Vaillant-Molina, under review).

The present study addressed the effects of intersensory facilitation across the life span by extending tests of intersensory facilitation and task difficulty to adult perceivers. Similar to our infant study, we anticipated that adults would show discrimination of tempo in bimodal audiovisual stimulation, but not in unimodal visual stimulation, particularly for difficult tasks.

Methods

Adults (N = 32) were familiarized with a single trial depicting a toy hammer tapping a 4-beat rhythm at a particular tempo (standard) under conditions of either unimodal visual or bimodal, synchronous, audiovisual stimulation (N = 16 each). Following presentation of the standard, they received 16 test trials in which there was no change in tempo (no change), a change of 25% (low difficulty), 17% (moderate difficulty), and 9% (high difficulty), with four trials of each difficulty level. Two blocks of trials were presented, each with a different standard tempo (159 or 192 bpm). The number of trials for which adults correctly discriminated the tempo change (same/different) was recorded.

Results

Analyses indicated a main effect of difficulty level with more correct responses for the no change and low difficulty trials than the moderate and high difficulty trials. Furthermore, consistent with predictions of intersensory facilitation, a main effect of condition emerged, with more correct responses for the bimodal than the unimodal condition, $F(1, 30) = 8.47$, $p = .007$. No interaction with task difficulty was found, however, the mean number of correct responses was low overall (3.8 out of 8), suggesting that the task was difficult for adults.

Conclusions

These results provide the first evidence that adult participants, like infants, show intersensory facilitation under conditions of audiovisual redundancy. Adults demonstrate enhanced processing and discrimination of amodal properties in the context of redundant, audiovisual stimulation as compared with unimodal visual stimulation. These findings converge with those of infant studies and indicate that predictions of the Intersensory Redundancy Hypothesis hold across the life span.

Auditory capture on the visual Ternus effect: the influence of subjective inter-sound interval

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Research on multi-sensory interactions has shown that the perceived timing of a visual event can be captured by a temporally proximal sound. This effect has been termed 'temporal ventriloquism effect (TVE)'. It has been found that the TVE can be influenced by both auditory grouping and audio-visual temporal structure. In the present study, using the Ternus display we demonstrated that the subjective inter-sound-interval is another important factor contributes to the TVE, which is reflected on the changes of the transition threshold between two different percepts of apparent motion: 'element motion' and 'group motion'.

In Experiment 1, the influences of dual-sound and multiple sounds on the visual apparent-motion were compared. The inter-sound-interval was fixed at 120 ms and each tone duration was 20 ms in both dual-sound and multiple-sound conditions. The transition threshold of two motion percepts was significant lower in dual-sound condition (117 ms) compared to that in multiple-sound condition (135 ms). The lower threshold means 'group motion' impression is dominant of the two alternative percepts, which indicates the ISI between two visual frames has been "dragged" longer. A further experiment on subjective inter-sound interval suggested that the inter-sound interval in the dual-sound was perceived 17 ms longer than that in multiple-sound with the physical equal interval(s) of 120ms. In Experiment 2, the transition thresholds of pure visual Ternus display and visual Ternus display with synchronous dual-sound, as well as the subjective inter-stimulus interval with and without sounds were compared. The results showed that the threshold between two apparent motion percepts was shifted lower in the condition with synchronous sounds by 25 ms. Furthermore, the results from subjective interval comparison suggested that subjective interval was longer with synchronous sounds than without sound.

In summary, the present study investigated the auditory-capture effect with the visual Ternus display using different auditory configurations. The same inter-stimulus interval leads to different capture effect. The main mechanism behinds this can be the subjective interval which itself is influenced by the auditory configuration.

Gone in a Flash: Manipulation of Audiovisual Temporal Integration Using Transcranial Magnetic Stimulation

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Audiovisual integration is a vital process that enables the creation of meaningful multimodal percepts. Previous evidence suggests that the right inferior parietal lobule plays a central role in audiovisual temporal integration; however, this role has not been explored by directly manipulating cortical activity. We employed the well-known sound-induced flash illusion, in which a single visual flash, when accompanied by two auditory tones, is misperceived as multiple flashes. Following administration of repetitive transcranial magnetic stimulation to the right angular gyrus, there was a significant decrease in the number of perceived flashes when single visual stimuli were presented with pairs of tones, reflecting a reduction in susceptibility to the illusion and an increase in perceptual accuracy. Stimulation of the right supramarginal gyrus did not affect the illusion. Perturbation of neural networks involved in multisensory temporal integration can induce changes in audiovisual processing resulting in a more veridical representation of audiovisual events. These data suggest that cross-modal binding is an active process in which the delineation of coherent entities in the environment takes precedence over temporal precision.

Phonetic recalibration only occurs in speech mode

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Upon hearing an ambiguous speech sound dubbed onto lipread speech, listeners adjust their phonetic categories in accordance with the lipread information (recalibration) that tells what the phoneme should be. Here we used Sine Wave Speech (SWS) to show that this tuning effect occurs if the SWS sounds are perceived as speech, but not if the sounds are perceived as non-speech. In contrast, selective speech adaptation occurred irrespective of whether listeners were in speech or non-speech mode. These results provide new evidence for the distinction between a speech and non-speech processing mode, and they demonstrate that different mechanisms underlie recalibration and selective speech adaptation.

The influence of auditory velocity cues on distance reproduction during simulated self motion

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Successful locomotion through space requires precise estimation of the direction and distance travelled ("path integration"). Previous studies showed that human subjects can use velocity information arising from visual, vestibular and somatosensory signals to reproduce passive linear displacements. In the present study, we investigated whether also auditory velocity cues influence the perception of travelled distances. In a first set of experiments, subjects had to reproduce a previously seen sequence of linear motion across a ground plane. Both in the passive and active displacement they heard a pure sinusoidal tone with a pitch being proportional to the simulated speed (test trials). Passive displacements had different constant velocities and distances. In twenty percent of the trials subjects heard white noise which was not modulated by the movement (catch trials). In both cases, test and catch trials, participants reproduced distances very accurately, i.e. the absence or presence of reliable auditory information had no apparent effect on the subject's performance. In a second set of experiments, the passive displacements had different velocity profiles (constant, sinusoidal, complex). In one fifth of the trials the relationship between optical velocity and tone frequency was differently scaled during the active displacements, i.e. the pitch of the tone was either 30% higher or 30% lower than in the passive displacement (re-scaling, catch trials). Again, in trials without re-scaling, subjects reproduced distances very accurately and tended to replicate the velocity profile of the passive condition. In the catch trials, however, subjects' performance was disturbed by the non-matching auditory velocity cue: When the pitch was 30% lower subjects used higher speeds, resulting in a substantial overshoot of travelled distance, whereas a higher pitch resulted in an undershoot of travelled distance. Our results clearly show that not only visual, vestibular and somatosensory signals but also auditory signals are used for path integration.

Integrating nonspatial, nontemporal multisensory information in action-based perception

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The study of multisensory perception has traditionally emphasized the integration of temporal and spatial aspects of events in nonaction settings. We adopted an action-based paradigm to investigate the factors affecting how nonspatial and nontemporal multisensory information is integrated. On a trial, participants struck a virtual object with a constant velocity and received feedback on correctness. When a performance criterion was reached, feedback was eliminated, the properties of the stimulus were changed, and the effects on striking velocity and performance were measured.

In Experiment 1, we studied the effects of the congruence of multisensory information and of a participant's expertise in the task. We studied a unimodal or a multisensory audio-haptic display in which the haptic and sound hardness of the object were manipulated. In multisensory trials, the audio-haptic changes could be congruent (e.g., both increased in hardness) or incongruent. We recruited participants with different levels of expertise with the task: percussionists, nonpercussionist musicians and nonmusicians. Overall, striking velocity decreased with an increase in both haptic and sound hardness. The level of expertise influenced the effects of haptic, but not of sound, hardness, where only percussionists struck harder haptic objects faster. For all participants, striking velocity in the multisensory trials was most strongly affected by changes in haptic hardness. Further, the effects of hardness were much more similar across participants in the auditory than in the haptic modality. Multisensory congruence modulated the effects of sound but not haptic hardness: whereas in congruent trials the effects of audio hardness were the same as in the unimodal condition, audio hardness was behaviorally irrelevant when it varied in opposition to haptic hardness. Overall, performance did not improve from the unimodal to the multisensory context. Only for nonmusicians was performance significantly better in the audio-only condition. In summary, the effects of the least relevant modality, audition, were more similar across individuals, were independent of expertise and were modulated by multisensory congruence. On the contrary, the effects of the primary modality, haptics, varied more across individuals, were influenced by expertise, and were independent of multisensory congruence.

In Experiment 2, we assessed the behavioral relevance of a visual property of the display. Nonmusicians were presented with either a visual or a visual-audio-haptic stimulus. We manipulated the speed of the visual striking object, and, in multisensory congruent trials, also the sound and haptic hardness. Participants wore a head mounted display. Striking velocity decreased for increasing haptic and sound hardness, and for decreasing speeds of the striking object. Future investigations will extend the results of Experiment 1 to visual-audio-haptic contexts.

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DAY 1 - MONDAY

Perceptual Interactions in the Detectability and Loudness of Combined Auditory-Tactile Stimuli

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We examined auditory (A) and tactile (T) interactions in two areas: (1) the detectability of A and T stimuli in unimodal and combined-modality (A+T) presentation as a function of stimulus level; and (2) the loudness of various combinations of A and T stimuli presented at supra-threshold levels. Auditory stimuli were pure tones presented binaurally through headphones in broadband noise; tactile stimuli were sinusoids delivered through a single-channel vibrator to the left middle fingertip. In the first experiment, performance was measured using a fixed-level 2I, 2AFC procedure for 250-Hz single-modality A and T stimuli and for four different A+T stimuli created through all combinations of the following stimuli: A at 0 and 2 dB SL and T at 0 and 2 dB SL, where the intensity corresponding to 0 dB SL was established under unimodal conditions. Preliminary results indicate that A+T performance is significantly higher than that obtained through either modality alone but that there are no significant differences among any of the combined A+T conditions, suggesting that A+T performance may have been limited by ceiling effects under the current methodology. In the second experiment, a 200-Hz auditory comparison tone was matched in loudness to various combinations of supra-threshold auditory and tactile stimuli (A+T) and purely auditory stimuli (A+A). The A stimuli were presented at a level of roughly 25 dB SL and the T stimuli were presented at a level that was matched roughly in loudness to that of the A stimuli. Preliminary results in this area indicate that the matched intensity of the comparison tone is less when the reference frequencies of the A+T and A+A stimuli are close together than when they are separated by an octave in frequency. This result suggests that A+T integration may operate in a manner similar to that found in auditory critical band studies, further supporting a strong frequency relationship between the auditory and somatosensory systems. [Work supported in part by a Hertz Foundation Fellowship and grants from the National Institutes of Health T32-DC000126-25 and ROI-DC000117].

The optimal time window of integration

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The notion of a spatiotemporal window of integration is a commonly accepted concept in multisensory research: crossmodal information falling within this window is integrated, whereas information falling outside of this window is not. It has been recognized, however, that integrating crossmodal information always involves a decision about whether or not two (or more) sensory cues originate from the same event, i.e., have a common cause [e.g., Koerding et al. PLoSONE, Sept. 2007]. Several research groups have shown by now that multisensory integration more or less closely follows rules based on optimal Bayesian estimation procedures. Here we extend this approach by determining the optimal width of a time window of integration: An infinitely large time window would lead to mandatory integration, a zero-width time window would rule out integration entirely. Computation of an optimal time window must be based on, amongst others, the a-priori probability of a common cause and the likelihood of observed temporal disparities between the unimodal signals. We demonstrate this approach within the framework of the time-window-of-integration (TWIN) model developed by the [Colonius & Diederich, JCogNeurosci 2004; Diederich & Colonius, BrainRes 2008].

Audio-visual speech perception and attention

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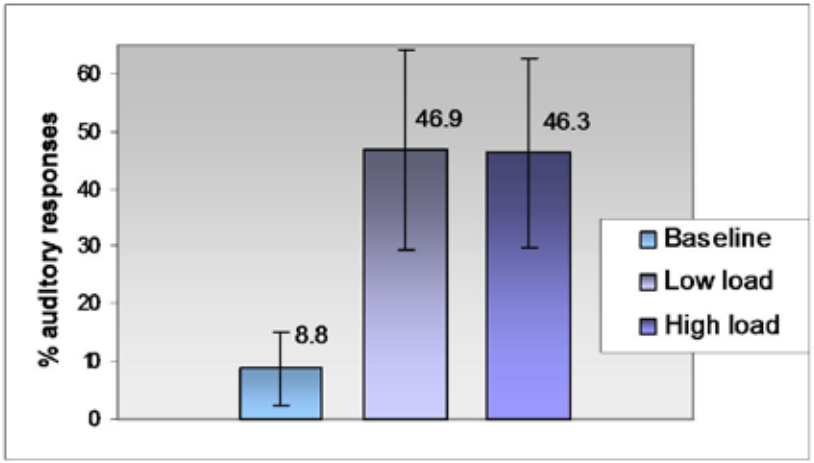
An increasing number of reports suggest that audio-visual (AV) speech integration is not completely automatic but instead depends on attentional resources (e.g., Alsius et al. 2005; Tiippana et al. 2003). Two aspects of attention seem to be crucial: the perceptual set (Tuomainen et al., 2005) and perceptual capacity (resources allocated to processing relevant stimuli and ignoring distracters, e.g., Lavie & Tsal, 1994). We investigated the latter issue by measuring susceptibility to the McGurk effect (e.g., an incongruent audio-visual pairing of auditory /aba/ with visual /aga/) while the participants (N=19) simultaneously performed a demanding primary visual task under conditions of high or low perceptual load with the instruction to ignore the articulating face. According to the 'perceptual load hypothesis' (Lavie & Tsal 1994) distracter stimuli (i.e., in the current experiment: the articulating mouth) are only processed if the detection of target stimuli in the primary visual task does not exceed attentional capacity limits. If this hypothesis is accurate then, especially under high perceptual load, we should observe an increase in the number of "auditory responses" on the "McGurk trials" (indicating reduced integration of auditory and visual speech signals) suggesting that AV speech integration is not a fully pre-attentive process.

The results showed a significant main effect of the attention manipulation ($p<0.001$); the low and high load conditions differed significantly from the baseline condition. However, we failed to find an increase in the attentional effect as a function of increasing perceptual load (Figure 1, see supplementary file).

The increase of task difficulty (perceptual load) as a function of the number of different nontargets was indicated by a significant reduction of the number of correct responses from low load condition (77%) to high load condition (58%) ($p<0.001$). The accuracy in the high load condition was not significantly different from chance. The accuracy was also significantly lower on incongruent trials than congruent trials ($p=0.026$).

The predictions of the perceptual load hypothesis were not completely supported by our results as increase in load did not further reduce integration. We speculate that under very high perceptual load subjects cannot constantly focus on the primary task and may be distracted by the mouth movements which automatically capture the attention.



Modality-Specific Clock Components and Memory Mechanisms: Evidence from Parallel Timing

Pierre-Luc Gamache, Simon Grondin

Université Laval

A time interval reproduction task involving the parallel timing of two sensory signals presented either in the same modality or in different modalities was conducted. A memory component was tested by manipulating the delay separating the presentation of the target intervals and the moment when the reproduction began. Results show that there is more variance when only visually marked intervals are presented, and this effect is exacerbated with longer retention delays; with only one interval to process, encoding the interval with signals delivered from two modalities contribute to reduce variance. The results suggest the existence of modality-specific clock components and memory mechanisms.

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Perceiving schematic faces and man-made objects using a visual-to-auditory sensory substitution activates the fusiform gyrus

Paula Plaza [1], Isabel Cuevas [1], Olivier Collignon [1], Cécile Grandin [2], Anne G De Volder [1], Laurent Renier [1]

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Previous neuroimaging studies identified the fusiform face area (FFA) in the ventral visual cortex as a region specialized in the visual processing of faces. Here, we tested whether the FFA was recruited as well when a prosthesis substituting vision by audition (PSVA) was used. Using functional magnetic resonance imaging in blindfolded volunteers, we compared the brain activation patterns during the categorization of faces, man-made objects and meaningless images with the PSVA. Face-related activation foci were found in occipito-temporal brain areas, including the fusiform gyrus in and around the FFA. Man-made objects activated a larger occipito-temporal network including the same coordinates as faces, whereas meaningless images did not recruit any visual brain area. We conclude that perception of different visual categories provided by sensory substitution involves the same brain structures as direct vision, indicating a specific functional organization of the ventral visual stream to allow perception of faces or man-made objects independently of the sensory modality.

DAY 1 - MONDAY

Recalibration of perceptual timing between one's own action and associated sensory feedback

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Our own actions always precede subsequent sensory feedback through which we can regulate the action. This temporal relationship between our own actions and the associated sensory feedback provides a clue for perceiving causality and discriminating the sensory feedback from other irrelevant sensory events. However, the judgment of the temporal order of an own action and a sensory event might be confounded, as the physical and neural delays of the sensory information are not accessible. This issue can be solved by statistical learning; that is, if a particular temporal difference between an action and a sensory event is very frequent, that event is likely to be the feedback. To prove the statistical learning hypothesis, we manipulated the temporal difference between an action and the sensory feedback. In this experiment, each session began with an adaptation phase during which the participants' voluntary button presses were coupled with noise bursts, and the actions and noise bursts were separated by a fixed time lag of -15, 0, 100, or 200 ms (the negative value indicates that the noise burst occurred first). Following the initial adaptation, the participants were asked to press the button again, and a noise burst was presented at one of several possible onset asynchronies relative to the button press. The participants made either 'sound-first' or 'tap-first' responses. The results showed that the point of subjective simultaneity shifted as a function of the adapted asynchronies, including the situation in which the feedback preceded the action, suggesting that the recalibration process is flexible. Recalibration indeed occurs, supporting the statistical learning hypothesis.

Olfactory processing in early blind subjects: psychophysical and functional magnetic resonance imaging study

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Previous studies have shown that early blind subjects (EBS) develop superior abilities in the use of their remaining senses, hypothetically due to a cross-modal reorganization of deafferented visual brain areas to process non-visual information such as sounds or tactile stimuli. However, the effects of blindness on olfactory processing are largely unknown. Here we used a battery of psychophysical tests to investigate olfactory discrimination and identification abilities in EBS and blindfolded sighted controls (BSS) matched for age, sex and handedness. To isolate the aspects related to the access to semantic information in the identification performance, three levels of cueing were used: free-identification (no-cue), semantic categorization, and multiple-choice identification. Then, using functional magnetic resonance imaging (fMRI) with an olfactometric system, we monitored the brain activity in the same subjects while they categorized and discriminated odors and auditory stimuli (words). Results showed that EBS significantly outperformed the BSS in odor discrimination, free-identification and categorization, but not in multiple-choice identification. EBS also activated more their occipital cortex during odor and auditory (words) discrimination and categorization tasks than BSS. However, no modality-specific activation were observed in the occipital cortex of EBS. We conclude that EBS have both superior perceptual abilities and a facilitated access to the semantic information stored in memory to recognize odors. The nonspecific cross-modal recruitment of the occipital cortex in EBS during both the olfactory and auditory processing confirms a functional role played by this cortex in non-visual processing, though its exact role still remains unsettled.

Audiovisual integration of emotional and linguistic signals in voice and face

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Purpose: Speech prosody serves numerous functions, including conveying information regarding meaning as well as emotion or affect. In addition during audiovisual speech processing, prosody interacts with visual cues to enrich and inform the meaning behind the utterance. Although there has been a surge of interest in examining the integration of auditory and visual cues in speech (phonetic) perception (Calvert & Campbell, 2003; Calvert, Campbell & Brammer, 2000) and in the perception of emotion (Ethofer et al., 2006; Kreifelts et al., 2007; Pourtois et al., 2005) there has been little direct comparison of the neural substrate for linguistic and affective processing. In the current report, we examine the neural substrate associated with unisensory and multimodal integration of cues in linguistic and affective judgments.

Methods: Ten healthy volunteers (5 males) were presented with semantically neutral sentences expressing affective or linguistic prosody solely through the use of non-verbal cues (intonation, facial expressions) while undergoing fMRI. The sentences were presented under auditory, visual, as well as audio-visual conditions. The emotional prosody task required participants to identify the emotion of the utterance (happy or angry) while the linguistic prosody task required participants to identify the type of utterance (question or statement).

Results: Affective and linguistic processing appear to rely on a common neural substrate for both unisensory and multisensory modalities. The multisensory network included bilateral occipital areas, multiple bilateral areas on the superior temporal gyrus (STG), the supramarginal gyrus, the right superior temporal sulcus (STS), bilateral fusiform region, and the pre-supplementary motor area. Within this common network, affective processing resulted in increased areas of activation in the pre-SMA, bilateral fusiform region, the left inferior occipital region, the caudomedial and lateral portions of the posterior STG (pSTG), as well as an area around the right STS. In contrast, linguistic processing resulted in increases in activation on the right lateral pSTG, left middle STG, the left superior temporal plane and the right inferior occipital region. Two areas in the right hemisphere (middle frontal gyrus and the lower border of the inferior frontal gyrus) were only activated for judging affect. Unisensory differences were found in an area around the supramarginal gyrus (SMG) in the left hemisphere associated with the affective judgment in both visual and auditory modalities while only the auditory modality activated the SMG for the linguistic judgment.

Conclusions: The model of speech prosody processing that emerges is, for the most part, one of overlapping bilateral activation for affective and linguistic prosody, with the strength of activation modulated by task demands and modality of presentation.

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DAY 1 - MONDAY

Perceptual constancy effects in taste discrimination

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Taste often takes time to develop and varies over mouthfuls, but we rarely perceive this. In other modalities, perceptual constancy acts to smooth over such variation and we test for effects on taste here. Taste-constancy may be driven by the assumption that food items are homogeneous in taste throughout. We developed a paradigm to prompt this assumption for drink-stimuli. In Experiments 1 and 2, participants sipped 2 drinks and indicated whether the two drinks tasted the same (using a sureness-scale). In some trials, the drinks appeared to be poured from the same jug, prompting the homogeneous-taste assumption. Taste constancy should reduce perceived differences in taste here and this was observed: same-jug drink-pairs were reported more similar than different-jug drink-pairs, in which the drinks were seen to be poured from different jugs. However, when we assessed whether a sweeter first drink had a greater impact on the perceived sweetness of the second drink in same-jug pairs, no evidence for taste-constancy was found for either the sweetness measure (Experiments 3 and 4) or the similarity rating (Experiment 4) suggesting that an analytical cognitive strategy acted to inhibit constancy here (Le Berre et al, 2008; Prescott et al, 2004). Summarising, our findings provide first support for taste constancy.

Le Berre, E., Thomas-Danguin, T., Beno, N., Coureaud, G., Etievant, P., & Prescott, J.
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Effects of a secondary task and working memory load on visual-proprioceptive multisensory integration when reaching

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It is uncertain whether optimal multisensory integration (see Ernst & Bülthoff, 2004) occurs in a purely perceptual bottom-up manner, or whether they also require executive resources to function adequately. If executive resources are required for optimal integration, then it should be possible to observe effects of secondary task performance and/or working memory load (WML) on the relative weighting of the senses under conditions of intersensory conflict. We examined the effect of a secondary task and WML on the relative weighting of visual and proprioceptive cues to hand location prior to reaching for a visual target. Visual and proprioceptive cues to the position of the right hand were put into varying degrees of conflict in the azimuthal plane and in radial depth by displacing the hand relative to an illusory visual image of it (provided by a mirror placed at the midline, facing the left hand; Holmes et al., 2004). The secondary task required participants to remember a string of digits whilst observing the (illusory) right hand under varying conditions of conflict and then reaching for a visual target of that hand. There were three conditions of load (No secondary task / Low WML; the string to be remembered was 01234 / High WML; the string to be remembered was a random series - e.g. 02143). Fig. 1 shows that WML increased visual capture by the illusion, regardless of the direction of visual-proprioceptive conflict ($F(1,14)=3.6$, $p<.05$). This effect of WML was driven by a significant difference in visual capture between the No WML condition and the Low WML condition – indicating that the executive demands of task-switching (rather than WML load) drives this effect. We conclude that, in this case, optimal multisensory integration requires executive resources.

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Holmes, N.P. et al. (2004) When mirrors lie: "Visual capture" of arm position impairs reaching performance. Cogn. Affective Behav. Neurosci. 4, 193-200

Short term memory for tactile stimuli presented on the fingertips and across the body surface

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Studies of visual short term memory have revealed that information that has not been explicitly reported during full report procedures can still be accessed when partial report procedures are used instead (e.g., Sperling, 1960). The aim of the present study was to investigate whether tactile information is also initially retained in a short-term store. In Experiment 1, participants reported the total number of tactile stimuli (up to 6) presented simultaneously to their fingertips (numerosity task). In another condition, after being presented with the tactile display, the participants had to detect whether or not the position indicated by a probe (visual or tactile) had previously contained a tactile stimulus (partial report task). Participants correctly reported up to 3 stimuli in the numerosity judgment task but their performance was far better in the partial report task: Up to 6 stimuli were perceived at the shortest target-probe intervals. This result demonstrates that although tactile information may be unavailable for report in a numerosity task it can nevertheless sometimes still be accessed using a partial report procedure instead. The fact that participants' performance was similar no matter whether the probe was visual or tactile further suggests that the processes underlying the encoding of the tactile stimuli presented in parallel on the fingertips have multisensory components.

In Experiment 2, a similar pattern of results observed when participants performed a concurrent articulatory suppression task, thus suggested that the encoding of spatial positions was not linguistic in nature. The results of Experiment 3 revealed that performance in the partial report task was overall better for stimuli presented on the fingertips than for stimuli presented across the rest of the body surface. However, in neither condition did concurrent articulatory suppression have any effect on participants' performance as compared with a silent condition.

Thus, greater sensitivity on the fingertips than on the rest of the body surface would seem to involve greater STM capacity in the absence of any difference in encoding processes. Thus, consistent with the literature on visual STM (see Irwin & Andrew, 1996, for a review), the results of the study reported here suggest that the information from a tactile scene that is stored for later report or comparison is typically represented in an abstract non-modality specific code.

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The left fusiform gyrus processes visual, tactile, and auditory features of manipulable objects

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The aim of this study was to identify brain regions involved in the recognition of object-specific features in the visual, auditory, and tactile modality. 18 right-handed, healthy participants underwent functional MRI while they performed a 1-back working memory task on visual, auditory or tactile stimuli. In different blocks, participants saw pictures of manipulable objects or pictures of surface textures, heard object sounds or sound textures, and touched 3-dimensional objects or surface textures. The order of blocks was pseudorandomized. For each sensory modality, we identified regional increases in blood oxygen dependent (BOLD) signal for object stimuli relative to high-level control stimuli. These contrasts were entered in a conjunction analysis to identify brain regions processing object-specific features across all three sensory modalities. Only a small cluster in the left fusiform gyrus showed increased activity during visual, auditory, and tactile object recognition. The right homologue region was also activated by visual and tactile object features but did not respond to auditory object features. Larger sets of cortical areas displayed object-specific BOLD responses for two out of three modalities. Visual and tactile processing of objects involved the lateral occipital complex and fusiform gyrus bilaterally; auditory and visual object processing only involved the left fusiform gyrus; auditory and tactile object recognition involved the left middle temporal cortex (near V5/MT+), superior parietal cortex, supramarginal, and fusiform gyrus. The present results show that left fusiform gyrus processes unimodal object-specific information in the visual, auditory, and tactile modality. This finding suggests that this region is a key area for multimodal integration of object-specific sensory input.

Visual experience supports haptic face recognition: Evidence from the early-and late-blind

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In previous experiments, we provided further evidence that the haptic and visual systems both have the capacity to process faces, and that face information can be shared across sensory modalities [1]. Interestingly, we found this information transfer across modalities to be asymmetric and limited by haptic face processing. Visual face perception relies on specific processes that evolve with perceptual expertise, while we have little to no training in haptic face recognition throughout life. We, therefore, suggest that the observed asymmetry in visual and haptic face processing might be attributed to different levels of expertise. To test the importance of visual experience with faces also for haptic recognition we studied haptic face recognition in the early-blind (N=10), late-blind (N=9) and sighted (N=18).

Participants performed an old/new recognition task for which sets of three faces were learned haptically, followed by three subsequent haptic test-blocks. We found that early-blind participants could recognize faces haptically, although recognition accuracy was low (d'= 0.83). More interestingly, however, recognition accuracy was significantly better in late-blind (d'=1.56) as well as sighted (d'=1.42) participants.

Our results, therefore, suggest that behavioral benefits in haptic face recognition require visual experience with faces. A lack thereof cannot be compensated for by purely perceptual haptic expertise as the results for the early-blind show. These findings suggest that haptic face recognition can recruit specific visual processing mechanisms that are shaped by visual experience [2].

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Multisensory processing and arousal modulation in the nematode C. elegans

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The nervous system of the nematode C.elegans, a tiny worm of 1 mm long, consists of 302 neurons, and all the synaptic connections (~ 7000 chemical and ~ 700 electrical synapses) were described by electron microscopic observation. Despite such simplicity of the nervous system, worms can sense and respond to various sensory stimuli including taste, odor, temperature, UV light and mechanical stimuli. Ease of genetic manipulation and its transparent body make it possible to control/ monitor activity of specific neurons in vivo with genetically-encoded tools. Finally, a huge repository of mutants allows us to examine the roles of genes in the nervous system. These characteristics will make C. elegans a good model to study multisensory processing in its simplest form, at multiple levels from gene to behavior.

Using C. elegans as a model, we are studying how sensory stimuli in different modalities interact each other in the nervous system. As sensory inputs, we are currently using two stimuli: actual mechanical stimuli to body and artificial activation of nociceptive neurons with light-gated ion channel channelrhodopsin-2, allowing precise control of stimulus strength and location. Analysis of behavioral response (withdrawal response) to these inputs so far indicated no sign of additive effect when the two inputs were presented simultaneously. However, when interval was given between the two stimuli, significant enhancement of response to the second stimulus with enhanced motor activity was observed. This result indicates there is 'arousal' change in the worm nervous system, which is also important to understand indirect interaction among different modalities. By screening available mutants, we also found that neuropeptide signaling plays a role in arousal modulation. Now we are trying to measure the activity of neurons in behaving worms using genetically-encoded activity sensors, to understand where and how this change is occurring at cellular level. Also, activity monitoring can possibly identify multisensory integration effect at cellular level despite that it was not identified behaviorally so far. We are also going to use stimuli in other modalities to discover novel interaction among them in multisensory integration and arousal modulation.

Audio-visual synchrony perception for stimulus onset and offset

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We examined whether the onset/offset of a stimulus affects audio-visual synchrony perception. The visual stimulus was a white light-emitting diode (LED). The auditory stimulus was a 1000-Hz tone that was presented through headphones. The stimulus duration was about 2 s in each modality. In all experiments, we measured the point of subjective simultaneity (PSS) using two tasks––a stimulus judgment task and a temporal order judgment task––using the method of constant stimuli. For each trial, a tone–light pair was presented or made to disappear with a lag that was chosen randomly from among nine values (-200, -150, -100, -50, 0, +50, +100, +150, +200 ms; a negative sign indicates whether the auditory stimulus appeared or disappeared first). In Experiment 1, we used the stimulus judgment task to examine the PSS for onset and offset of the audio-visual pair: participants made a yes–no judgment about whether the stimulus appeared or disappeared in synchrony. Results of Experiment 1 show that the PSS for onset timing was about -48.2 ms; that for offset timing was about +50.6 ms. For Experiment2, we used a temporal order judgment task to measure subjective simultaneity: participants judged whether a tone or light appeared or disappeared first. Results of Experiment 2 showed that the PSS was about -55.2 ms lag for stimulus onset timing. In contrast, it was about -4.6 ms for stimulus offset timing, suggesting that audio-visual synchrony perception processes differ between onset and offset of stimuli.

From bench to battlefield: Translating multi-modality research to system design

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Rapid technological advancements have lead to increasingly complex systems that combine both traditional and novel information-rich, multi-sensory displays; unchecked, there is the potential to overwhelm system operators. In particular, Soldiers operate within highly dynamic environments and must contend with challenging conditions including fatigue, emotional and physical stress, weather, darkness, and dust. System designs must not only be able to function reliably under these wide ranging conditions, but they must also function with operators of differing capabilities. One approach to enabling such systems design is to integrate our fundamental understanding of human behavior developed through neuroscience techniques into such designs. However, this is not a trivial undertaking. We seek to develop a framework for the translation of basic neuroscience to battlefield application. This talk will discuss critical aspects of translational work, such as understanding the function of the nervous system within dynamic real-world settings, and the transition from neuroscience to system development. It is in the context of these challenges that we are developing a framework to understand the complex interactions among human, task, and environment that are critical to the translation of multi-sensory theory to multimodal battlefield applications. Current efforts toward this goal will be discussed, including a description of current issues in both research and application domains, as well as interests for the future.

Tactile Temporal Processing in the Auditory Cortex

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Perception of the outside world results from integration of information simultaneously derived via multiple senses. Increasing evidence suggests that the neural underpinnings of multisensory integration extend into the early stages of sensory processing. In the present study we investigated whether the superior temporal gyrus (STG), an auditory modality-specific area, is critical for processing of tactile events. Transcranial magnetic stimulation (TMS) was applied over the left STG and the left primary somatosensory cortex (SI) at different time intervals (60 ms, 120 ms, 180 ms) during a tactile temporal discrimination task (experiment 1) and a tactile spatial discrimination task (experiment 2). Tactile temporal processing was disrupted when TMS was applied to SI at 60 ms after tactile presentation, confirming the modality-specificity of this region. Crucially, TMS over STG also affected tactile temporal processing but at 180 ms delay. In both cases, the impairment was limited to the controlateral touches and was due to reduced perceptual sensitivity. Instead, tactile spatial processing was impaired only by TMS over SI at 60-120 ms. These findings demonstrate the causal involvement of auditory areas in processing the duration of somatosensory events, suggesting that STG might play a supramodal role in temporal perception. Furthermore, the involvement of auditory cortex in somatosensory processing supports the view that multisensory integration occurs at an early stage of cortical processing.

Early visual deprivation alters multisensory processing in peripersonal space

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The multisensory peripersonal space develops in a maturational process that is thought to be influenced by early sensory experience. We investigated the role of vision in the effective development of audiotactile interactions in the peripersonal space. Early blind (EB), late blind (LB) and sighted control (SC) participants were asked to lateralize auditory, tactile and audiotactile stimuli. The experiment was conducted with the hands uncrossed or crossed over the body midline. First, we observed that the crossed posture had detrimental effects on the processing of all stimuli types in SC and LB. In EB however, crossing the hands did not significantly impair tactile stimulus processing. Second, we demonstrate that improved reaction times observed in the bimodal conditions in SC and LB are related to nonlinear neural summation in both conditions of postures, indicating neural integration of different sensory information. In EB, nonlinear summation was obtained in the uncrossed but not in the crossed posture. We argue that the absence of a detrimental "crossed-posture effect" for tactile processing in EB is attributable to a lack of automatic external remapping of touch and proprioception. Such default use of an anatomically anchored reference system in EB prevents effective audiotactile interactions in the crossed posture due to the poorly aligned spatial coordinates of these two modalities in such condition. These results provide compelling evidence for the critical role of early vision in the development of the multisensory peripersonal space.

Young and old process audiovisual speech more efficiently than auditory speech: an ERP study of audiovisual speech in noise

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Background: In a sample of young adults (YA) and older adults (OA) we employed event-related brain potentials (ERPs) to examine audiovisual (AV) speech in background babble noise. There is ample evidence that even healthy OA with clinically normal hearing thresholds manifest deficits in speech perception particularly in noisy environments. We were interested in the extent to which visual speech cues can offset those perceptual deficits and how whether the brain processes underlying AV speech integration differ in OAs and YAs. According to the inverse effectiveness hypothesis, older adults, relative to young adults, should gain more from multisensory cues due to their age-related sensory decline. Method: ERPs were recorded while participants categorized 80 spoken words as either natural (e.g., tree) or artificial objects (e.g., bike) via button press responses. Young adults (N=12; mean age = 24.3) and older adults (N=9; mean age = 68.6) had clinically normal visual contrast sensitivity and hearing thresholds and were cognitively healthy. Participants were presented in a random order with single spoken words in unimodal auditory-alone (A) and visual-alone (V) trials (i.e. lip-reading) and in a bimodal (AV) modality. We adjusted the signal/noise ratio in the A-only modality to equate the groups on perceptual load, to be able to measure the gain obtained by adding visual speech cues (i.e., visual enhancement effect).

Results & Discussion: Compared to unimodal trials, responses to AV trials were the fastest and most accurate for both age groups ($p < .001$). In young and older adults this AV benefit was accompanied by a reduced amplitude of the auditory N1 ERP component at central sites compared to A-alone trials ($p=.03$) and to the summed response of unimodal trials (A+V) ($p<.01$). Furthermore, the N1 peaked significantly earlier (22ms) during AV trials ($p<.001$). This indicates that the addition of visual speech cues enabled more efficient speech processing because speech perception is more accurate and faster yet

fewer neural resources are recruited. Interestingly, we did not see a main effect of Age nor an Age by Condition interaction when comparing responses to A-only and AV trials. In other words OA are as proficient in integrating auditory and visual speech cues as YA, and hence benefit just as much from audiovisual speech when the signal/noise is equated for A-only performance. Noteworthy is the fact that OA performed less accurate than YA in the V-only (lipreading) task (p=.006). However, when both modalities were combined in the AV condition OA performed as well as YA. This means that, with respect to the V-only condition, OA benefitted more from AV speech than YA. These results are consistent with the inverse effectiveness hypothesis which states that the less efficient unisensory information processing is the more is to be gained from combining the unisensory signals.

Do Dynamic Visual Analogues Aid Detection of Auditory Stress Patterns in Dyslexia?

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Individuals with dyslexia have subtle difficulties with basic auditory processing, in particular with respect to amplitude envelope structure. These auditory difficulties appear to reduce sensitivity to speech rhythm and prosody, and affect the syllabic segmentation of the speech stream. In non-dyslexics, visual cues to speech can greatly enhance speech intelligibility. This enhancement is most marked under conditions where the auditory input is less reliable (eg. in a noisy environment). Accordingly, visual input may aid prosodic perception in developmental dyslexia. In this experiment, we asked adults with dyslexia to detect stressed syllables when they heard spoken tokens either with synchronous delivery of congruent visual information or in the absence of this information. Two different visual analogues for the amplitude envelope of each token were created by transforming auditory intensity values into 2D motion in visual space. Dyslexic and control participants made same-different judgments about the placement of stress in pairs of 4-syllable words such as 'CAterpillar' and 'DANdelion'. Their performance in the baseline auditory-only condition was compared with performance in the two bimodal conditions. Testing is ongoing, but results are expected to shed light on whether adults with dyslexia and subtle auditory processing difficulties can benefit from cross-modal support in the form of dynamic visual displays.

Visual-Auditory Synchrony Boosts BOLD Response in Posterior Temporal and Occipital Cortices

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Introduction: Synchrony is a powerful cue for driving multisensory integration of dynamic stimuli and multisensory integration increases perceptual reliability. Thus ambiguous, dynamic, visual targets should be more accurately perceived when accompanied by concurrent auditory stimuli. For example, when a creature moving through the undergrowth is obscured by both intervening foliage & conditions of poor illumination, it may be more readily identified when the sound of each footfall is audible - heralding motion of figure against background and foreground. This fMRI study was designed to identify the neural correlates of synchrony-induced multisensory integration during shape and motion discrimination.

Methods: 16 subjects participated in this fMRI study (Siemens Allegra 3 T scanner, GE-EPI, TE=30, 38 axial slices, TR=3.08s). The 2x2 factorial design manipulated audiovisual synchrony (synchronous vs. asynchronous) and task (motion vs. shape discrimination). In a visual selective attention paradigm, subjects discriminated the shape or rotational motion of a dot array obscured by a rapidly-moving snow field. Each 2.5s trial consisted of 5 visual events that occurred at unpredictable intervals to eliminate anticipatory effects associated with regular stimulus timings. In 50% of the trials, each visual event was accompanied by a simultaneous 50ms "click" sound (synchronous condition), whilst in the other 50% the auditory and visual events were offset by at least 120ms (asynchronous condition). Visual events were discrete rotations of one of 32 different symmetrical, concentrically distributed, dot arrays. Synchronous and asynchronous trials were presented in randomised order and task order was counterbalanced within and across subjects. To allow for a random-effects analysis (SPM5), contrast images for each subject were entered into second level one-sample t-tests. We tested for the main effects of synchrony and task and their interactions. Effects are reported at $p<0.05$ whole brain corrected.

Behavioural Results: Subject performance was significantly more accurate under conditions of visual-auditory synchrony than asynchrony, whilst there was no significant difference in performance between the shape and motion tasks. The interactions indicate a significant performance improvement during synchronous trials for the motion task, but not the shape task.

fMRI Results: In bilateral posterior occipital cortices audiovisual synchrony amplified the BOLD response, irrespective of task. In contrast, in lateral occipital cortex (LOC) and posterior superior temporal (pSTG) / supramarginal (SMG) gyri, synchrony-induced activation increases were task dependent: in LOC synchrony effects were selective for shape discrimination, whilst in pSTG/SMG they were selective for motion discrimination. Discussion/conclusion: Our results suggest that, under noisy visual conditions, visual perception can be enhanced by concurrent acoustic stimulation in the following way: Audiovisual coincidence may enhance saliency of visual stimuli by amplification of visual responses in occipital cortex and thus lead to improved figure-ground segmentation. These are then further amplified in higher order LOC and pSTG/SMG in a task-selective fashion.

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DAY 1 - MONDAY

Thermal intensity perception under thermo-tactile interaction

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Thermal referral is first demonstrated with touching three stimulators with the middle three fingers of one hand. When the outer two stimulators were cold (warm) and the center stimulator was thermally neutral, cold (warmth) was felt at all three fingers. This illusion has been shown to result from the mislocalization of thermal sensations to the site of simultaneous tactile stimulation. Although the influence of the simultaneous tactile stimulation on the thermal localization has been studied extensively, its influence on the perceived thermal intensity has not yet been explored. Therefore, the present study investigated whether the simultaneous tactile stimulation also affects the perceived thermal intensity. We first investigated the perceived thermal intensity under no referral condition, in which two thermal stimulators were presented to two of the three fingers while the other finger held in the air. The stimulation levels of these two thermal stimulators, Tsti, were ±5, 7 , and 10 degree C. The perceived thermal intensity at the two fingers under different stimulation levels was evaluated by comparing it to the perceived thermal intensity produced by the reference stimulation presented to the corresponding three fingers of the other hand. The level of the reference stimulation varied according to the adaptive staircase method to determine an equivalent stimulation level, Teqv, at which the thermal intensity perceived at two hands were the same. The results indicated the relation between Teqv and Tsti to be: Teqv = 0.79 Tsti for cooling and Teqv = 0.80 Tsti for warming. The same procedure was adopted to investigate the perceived thermal intensity under thermal referral condition. The only difference was that the finger that was held in air in the previous experiment was now touched the neutral stimulator. The relation between Teqv and Tsti under thermal referral condition was found to be: Teqv = 0.63 Tsti for cooling and Teqv = 0.60 Tsti for warming. An one-way ANCOVA with experimental condition (no referral / thermal referral condition) as the fixed factor, Tsti as the covariate and Teqv as the dependent variable indicated that the perceived thermal intensities are significantly different between two experimental conditions for both cooling and warming stimulation. These results demonstrated the influence of the simultaneous tactile stimulation on the perceived thermal intensity and indicated the redistribution of thermal sensations under thermal referral.

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DAY 1 - MONDAY

The effects of temporal synchrony and visual material on audio-visual integration

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Associating letters with speech sounds is essential when learning to read. Recent studies on audio-visual integration suggested that 1) the integration of letter and speech sound takes place automatically and 2) that temporal synchrony is critical for the integration. In the current study, we wished to determine the neural networks associated with an automatic integration of written and heard syllables in literate adults. The mismatch negativity (MMN), an index of automatic change detection in the brain, was recorded. Subjects were presented with auditory stimuli (consonant-vowel syllables) together with visual stimuli, which differed between conditions. The auditory stimuli included vowel or consonant changes, or changes in syllable intensity, frequency, or vowel length. In the experimental condition the visual stimuli were written syllables, whereas in the control condition, they were scrambled images of the written syllables. The visual stimuli were presented in half of the blocks synchronously with the auditory stimuli and in the other half with a time delay. During the stimulation, the subjects pressed a button to designated visual targets. Changes in auditory stimuli elicited an MMN/N2 response, in all conditions. The type of visual material (syllables vs. scrambled images) as well as the timing of presentation (delay vs. no delay) influenced the topography of this response. The results indicated that different neural networks are activated when speech stimuli are presented together with linguistic than with non-linguistic visual stimuli and that this effect is modulated by temporal synchrony. Implications for dyslexia are discussed.

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Asynchrony adaptation induces non-uniform changes in perceived timing

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We typically perceive external events as coherent multisensory entities – if a balloon pops in front of us for example, we see and hear it happen simultaneously. That this occurs is not trivial, given that considerable differences exist between both the speed of light and sound through air, and the rate at which each is transduced into neural signals by our senses. A flexible strategy the brain could employ to support accurate temporal perception might be to monitor the temporal statistics (e.g. cross-correlation) of sensory input and correct for pervasive delays between modalities. Recent studies demonstrating that an observer's point of subjective simultaneity (PSS) can be altered by a short period of exposure to a consistent temporal delay are consistent with this view (e.g. Fujisaki, Shimojo, Kashino & Nishida, 2004; Vroomen, Keetels, de Gelder & Bertelson, 2004). However, at present it is unclear whether these experience-dependent changes are specific to the perception of simultaneous events, or are indicative of a general recalibration of perceived timing. To address this issue, we measured the effect of asynchrony adaptation on the perception of a wide range of sub-second temporal relationships. Observers were required to estimate the magnitude of the stimulus onset asynchrony (SOA) between pairs of brief auditory (broadband click convolved with head-related transfer functions) and visual (isotropic Gaussian blob) stimuli with and without prior adaptation to a fixed asynchrony (± 100ms SOA). In a preliminary analysis, we used the polarity of perceived SOA estimates (i.e. visual-first or auditory-first) to reconstruct psychometric functions for temporal order discrimination and derive PSS estimates. Shifts in the PSS following adaptation were comparable to those reported in previous studies. More detailed analysis of the dataset revealed that adaptation-induced biases were not uniform across the range of SOAs tested. Surprisingly, we found that the largest shifts in perceived timing occurred for SOAs of opposite polarity to that of the adapting stimulus (i.e. adapting to an auditory lead increased the perceived magnitude of subsequent visual leads). These results are inconsistent with a simple recalibration mechanism tasked with correcting relative processing delays between sensory modalities.

DAY 1 - MONDAY

Mixed Emotions: Audition can modulate the visual perception of the emotion of a crowd

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The ability to recognize the emotional state of another person or persons is an important social skill. Moreover, efficient emotional perception determines the appropriate response action. Although many studies have investigated the processes involved in investigating the perception of emotion from individual facial expressions or body postures, very little is known about how we perceive emotions from a crowd of individuals. Furthermore, our understanding of how the visual and auditory senses combine to influence the perception of the emotion of a crowd is poor.

We previously found that the emotion conveyed by a crowd can be accurately determined using vision only and that the visual categorization of a crowd is efficient even when the emotion is not consistent across the individuals in the crowd. In the current study we investigated the role of auditory information on the perception of the visual emotion of the crowds. Our stimuli comprised of audio-visual dynamic displays of crowds of varying levels of emotional consistency, from highly consistent to ambiguous. The emotions expressed were anger, fear, happiness and sadness. The auditory emotional cue was paired with each visual display such that it was consistent with one of the emotions visually displayed. We used a 4-AFC design and the participant's task was to categorise the visual emotion but to ignore the auditory information. We found that the auditory emotion significantly biased the perception of the emotion in the visual crowd, particularly when the emotion was visually ambiguous (e.g. half of the individuals in a crowd were fearful whereas the other half were sad). Our findings suggest that auditory emotional information can modulate the visual perception of the emotion of a crowd and have important implications for our understanding of emotional cognition.

Auditory capture on the visual Ternus effect: the influence of subjective inter-sound interval

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Research on multi-sensory interactions has shown that the perceived timing of a visual event can be captured by a temporally proximal sound. This effect has been termed 'temporal ventriloquism effect (TVE)'. It has been found that the TVE can be influenced by both auditory grouping and audio-visual temporal structure. In the present study, using the Ternus display we demonstrated that the subjective inter-sound-interval is another important factor contributes to the TVE, which is reflected on the changes of the transition threshold between two different percepts of apparent motion: 'element motion' and 'group motion'.

In Experiment 1, the influences of dual-sound and multiple sounds on the visual apparent-motion were compared. The inter-sound-interval was fixed at 120 ms and each tone duration was 20 ms in both dual-sound and multiple-sound conditions. The transition threshold of two motion percepts was significant lower in dual-sound condition (117 ms) compared to that in multiple-sound condition (135 ms). The lower threshold means 'group motion' impression is dominant of the two alternative percepts, which indicates the ISI between two visual frames has been "dragged" longer. A further experiment on subjective inter-sound interval suggested that the inter-sound interval in the dual-sound was perceived 17 ms longer than that in multiple-sound with the physical equal interval(s) of 120ms.

In Experiment 2, the transition thresholds of pure visual Ternus display and visual Ternus display with synchronous dual-sound, as well as the subjective inter-stimulus interval with and without sounds were compared. The results showed that the threshold between two apparent motion percepts was shifted lower in the condition with synchronous sounds by 25 ms. Furthermore, the results from subjective interval comparison suggested that subjective interval was longer with synchronous sounds than without sound.

In summary, the present study investigated the auditory-capture effect with the visual Ternus display using different auditory configurations. The same inter-stimulus interval leads to different capture effect. The main mechanism behinds this can be the subjective interval which itself is influenced by the auditory configuration.

Auditory Stimuli Induce a Desynchronization of Steady-state Visual Evoked Potentials

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Our brain has a limited in capacity for processing concurrent information streams. While the limitations of processing capacities have been extensively studied within the visual modality, less is known about how processing capacities are limited across sensory systems. Using EEG, we investigated how auditory stimuli modulate the processing of visual input at early perceptual stages. Participants were asked to detect brief deviant visual or auditory stimuli while viewing a continuous steady-state visual stimulation. Both visual and auditory stimuli elicited a desynchronization of the steady-state visual evoked potentials (SSVEPs) between 300~500ms following the transient event. These results suggest that early visual cortex activity is subject to both within-modality and between-modality competition.

Visuo-Motor versus Audio-Motor Temporal Recalibration

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Purpose
Previous research has shown that the timing of the sensorimotor system is recalibrated after a brief exposure to a delayed feedback of voluntary actions. Here, we compared lag adaption for action-feedback in motor-auditory pairs versus motor-visual pairs.

Methods
Participants were repeatedly exposed to a constant lag (~150 ms) between their voluntary action (a tap) and a feedback stimulus (a visual flash or auditory click). After 240 exposure trials, participants performed a temporal order judgment (TOJ) task on the same tap-feedback pairs. A subjectively no-delay (~50 ms) adaptation phase was used as a control condition.

Results
Brief exposure to the action-feedback asynchrony resulted in a shift of the Point of Subjective Simultaneity (PSS) in the direction of the exposed lag in both the motor-visual pair (a temporal recalibration effect, TRE, of 31 ms) and in the motor-auditory pair (TRE = 29 ms). The Just Noticeable Differences (JNDs) were not changed by lag exposure (see Figure 1).

Conclusions
The PSS data suggested that motor-sensory temporal perception was flexible irrespective of the feedback modalities. The JND data showed that a temporal window of simultaneity did not widen by the lag exposure in both modalities.

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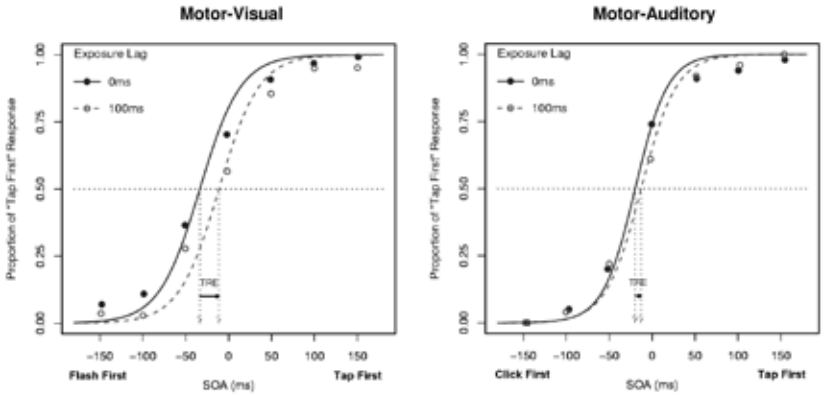

DAY 1 - MONDAY

Auditory influences on the temporal dynamics of binocular rivalry

Verena Conrad, Andreas Bartels, Mario Kleiner, Uta Noppeney

Max-Planck-Institute for Biological Cybernetics

Introduction
When the two eyes are presented with dissimilar images, human observers report alternating percepts – a phenomenon coined binocular rivalry. These perceptual fluctuations reflect competition between the two visual inputs both at lower, monocular and at binocular, higher-level processing stages. Even though perceptual transitions occur stochastically over time, their temporal dynamics can be modulated by changes in stimulus strength, context and attention. While increases in stimulus strength (such as contrast) primarily abbreviate suppression phases of a percept, attentional and contextual factors predominantly lengthen its dominance periods.

Goals
This project investigates the influence of concurrent auditory stimulation on the temporal dynamics of binocular rivalry. In two psychophysics studies, we investigated whether sounds that provide directionally congruent, incongruent or no motion information modulate the dominance periods of rivaling visual motion percepts.

Methods
In the first psychophysics study, observers dichoptically viewed random-dot kinematograms (RDK) at 0% motion coherence in one eye and 50% in the other in a stereoscope, while being concurrently presented with directionally congruent auditory motion, noise and no sound. In the second psychophysics study, they viewed two RDKs of opposite motion directions at 100% coherence, with the auditory motion stimulus being directionally congruent with one of the two rivaling motion percepts. In both experiments, congruent auditory motion was temporally synchronized with visual motion to facilitate audio-visual integration into a coherent percept.

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Initial results
Both experiments consistently revealed a statistically significant influence of sound on perceptual dominance times. In the first experiment, directionally congruent auditory motion but not noise increased the duration of the dominance phases of the RDK at 50% motion coherence. In the second experiment, auditory motion lengthened the dominance periods of the directionally congruent 100% RDK and abbreviated those of the directionally incongruent 100% RDK.

Initial conclusions
The results demonstrate that auditory stimuli influence the temporal dynamics of binocular rivalry. Auditory motion lengthened the dominance periods of a visual motion percept when it was directionally congruent, but shortened them when it was directionally incongruent. Thus, the (in)congruency of auditory motion pimarily influences the duration of the dominance periods similar to purely visual contextual effects, even though a small effect was also observed on the supression periods. In conclusion, the human brain draws on information from multple senses to arbitrate between multipl rivaling perceptua interpreatios

DAY 1 - MONDAY

The cerebral network involved in the cross-modal interactions between human faces and voices during recognition

Frederic Joassin [1], Pierre Maurage [1], Mauro Pesenti [1], Emilie Verreckt [1], Raymond Bruyer [1], Salvatore Campanella [2]

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Faces and voices are key features in human recognition. If the cerebral regions involved in the processing of both information are well known, the way the brain links them together is still largely unknown. Here we measured brain activity using fMRI while participants were recognizing previously learned faces, voices and voice–face associations.

14 healthy participants took part in this study. All were right-handed, french native speakers and had normal vision and audition. Stimuli consisted in 4 associations between a female face, a female voice saying the french word "Bonjour", and a belgian family name. Prior to the fMRI session, a training session served to familiarize the participants with the associations. During the fMRI session, 3 conditions were presented: faces alone (F), voices alone (V), and face-voice associations (VF). Participants had to categorize each stimulus according to its identity (its family name).

Using a subtraction method between bimodal and unimodal conditions [(VF-(V+F)], we observed that face-voice associations activated both unimodal visual and auditory areas, and 2 multimodal convergence regions located in the left angular gyrus and the right hippocampus. An enhanced connectivity of the hippocampus with unimodal areas was confirmed by a functional connectivity analysis, while the left angular gyrus showed an enhanced connectivity with premotor and frontal regions.

The present results demonstrate that binding faces and voices relies on the activation of a cerebral network implying the unimodal face and voices areas as well as specific integration regions, such as the left angular gyrus possibly involved in some processes of divided attention between visual and auditory inputs, and the right hippocampus in which inputs from visual and auditory regions may be integrated into a coherent face-voice representation which could be compared with those stored in memory.

Neural modulation of felt and seen touch on one's own face: a fMRI study

Flavia Cardini [1], Marcello Costantini [2], Gaspare Galati [3], Elisabetta Làdavas [4], Andrea Serino [4]

[1]Centro di Neuroscienze Cognitive, Cesena, [2]ITAB Institute for Advanced Biomedical Technologies, Foundation University "G. d'Annunzio", Chieti, [3]Department of Psychology, Sapienza University, Roma, [4]Department of Psychology, University of Bologna

The perception of tactile stimuli on the face is enhanced if subjects concurrently observe a face being touched; this effect, called visual remapping of touch, is maximum for observing one's own face. In the present fMRI study, we investigated the neural basis of this effect. Participants in the scanner received tactile stimuli, near the perceptual threshold, either on their right, left or both cheeks. Concurrently they watched movies depicting their own face, another person's face or a ball that could be touched or only approached by human fingers. Participants were requested to distinguish between unilateral and bilateral tactile stimulation. Tactile perception was enhanced when viewing one's own face being touched. This effect was related with a reduced activity, bilaterally, in both the ventral premotor cortex and the somatosensory cortex.

Ventral premotor cortex might underlie the self-related enhancement of visual remapping of touch. This area is part of a fronto-parietal network subserving the representation of the Embodied Self by integrating multisensory information related to the body. The neural modulation of ventral premotor cortex is then reflected to the somatosensory areas, thus affecting tactile perception.

Visual take-over in postlingually deafened adult cochlear implant users

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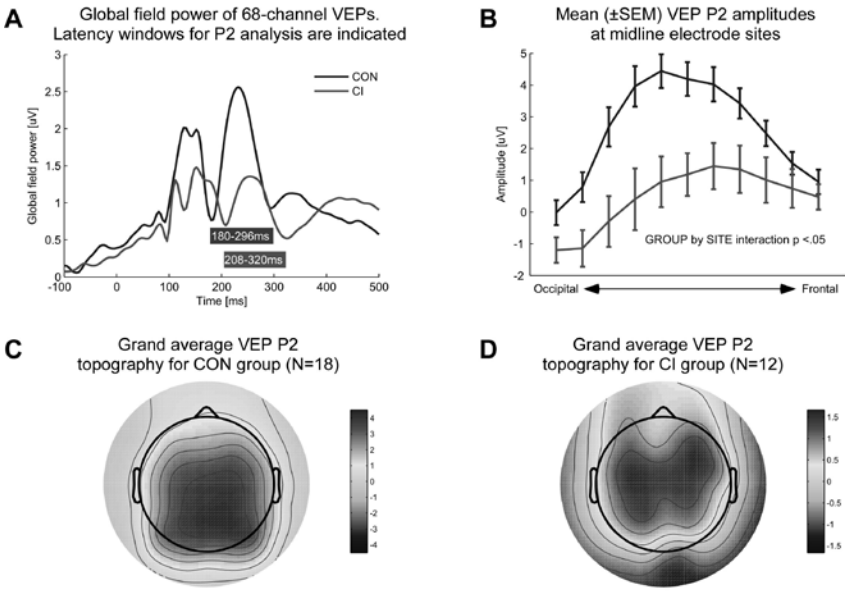
[2]MRC Institute of Hearing Research, Royal South Hants Hospital, Southampton,
[3]Department of Neurophysiology and Pathophysiology, Center of Experimental Medicine, University Medical Center Hamburg-Eppendorf, Hamburg, Germany

During deafness, the visual system takes control of auditory cortex capacity, a phenomenon known as visual take-over. However, how deafness-related compensatory plasticity relates to clinical outcome after cochlear implantation (CI) is not well understood. In an ongoing study, we compared visual evoked potential (VEP) topographies from 12 post-lingually deafened adults using a CI with a sample of 18 normal hearing controls. Visual stimuli were taken from the Multimodal Stimulus Series (cf. www.debener.de) and presented in an audio-visual semantic priming paradigm while EEG was recorded from 68 scalp sites. Inspection of VEP amplitudes and latencies suggested a number of group differences. For instance, P2 amplitudes at midline electrodes revealed a Group x SITE interaction ($p<.05$) that remained significant after vector normalisation. As predicted, CI users showed a more anterior distribution in the P2 latency range (see supplemental figure). A source-based analysis of the visual take-over phenomenon will be presented and the results will be discussed with regard to the clinical performance of CI users.

Visual evoked potentials (VEPs) in normal hearing controls (CON) and post-lingually deafened adults using a cochlear implant (CI)



Enhanced Sensory Perception in Synaesthesia

Michael Joseph Banissy [1], Vincent Walsh [1], Jamie Ward [2]

[1]University College London, [2]University of Sussex

Previous findings imply that synaesthetic experience may have consequences for sensory processing of stimuli that do not themselves trigger synaesthesia. For example, synaesthetes who experience colour show enhanced perceptual processing of colour compared to non-synaesthetes. This study aimed to investigate whether enhanced perceptual processing was a core property of synaesthesia by contrasting tactile and colour sensitivity in synaesthetes who experience either colour, touch, or both touch and colour as evoked sensations. For comparison the performance of non-synaesthetic control subjects was also assessed. There was a relationship between the modality of synaesthetic experience and the modality of sensory enhancement. Synaesthetes who experience colour have enhanced colour sensitivity and synaesthetes who experience touch have enhanced tactile sensitivity. These findings imply that a hyper-sensitive concurrent perceptual system is a general property of synaesthesia and are discussed in relation to theories of the condition.

Olfactory function is correlated to cortical thickness of chemosensory and non-chemosensory regions

Johannes Frasnelli

Université de Montréal

In recent years, objective whole-brain techniques (voxel-based morphometry, VBM) have become available that allow segmentation of brain structures into grey matter, white matter and cerebrospinal fluid. In the present study we used them to investigate the correlation between individual grey matter thickness and olfactory function. Forty-six subjects (27 women, 19 men) underwent extensive olfactory testing including odor identification, detection thresholds, intensity discrimination and quality discrimination. The behavioral results and subjects' anatomical MRI scans were analyzed using two MNI in-house programs (CIVET, Surfstat).

A global analysis demonstrated that subjects with better overall performance had a significantly thicker cortex in the right dorsal postcentral gyrus and the right insula. Moreover, a region of interest analysis revealed a correlation of olfactory function with grey matter thickness in the right medial orbitofrontal cortex.

Of the individual olfactory tasks, odor identification was correlated with gray matter thickness in the right anterior transverse temporal gyrus, adjacent to the right insula, where quality discrimination showed an association with cortical thickness. Quality discrimination was also associated with grey matter thickness in the right intraparietal sulcus and pre- and postcentral areas bilaterally, considered being responsible for voluntary respiration and sniffing. In addition, in the right entorhinal cortex, occipital cortex, and insula the correlation between olfactory function and cortical thickness was different for women and men, possibly showing a biological underpinning for sex differences in olfactory performance.

These results indicate that performance on individual olfactory tests is reflected in brain anatomy, in both classical chemosensory areas as well as in areas usually considered to be dedicated to other (sensory) tasks.

Neural correlates of disambiguating an ambiguous multisensory motion stimulus

Benjamin Taylor Files [1], Lynne E Bernstein [2]

[1]University of Southern California, Los Angeles, [2]House Ear Institute, Los Angeles

Vision appears to be the dominant influence when we interpret motion in the world around us, but information from the other senses can help to interpret an otherwise ambiguous stimulus. An example of this is the bounce/stream illusion. The bounce/stream illusion arises in the context of an ambiguous visual display in which two identical objects approach each other, overlap and then move apart. This visual display is typically interpreted in one of two ways: the two objects exchanged trajectories at the point of overlap (i.e., they 'bounced' off each other) or the two objects each continued on their original trajectories (i.e., they 'streamed' through each other). Although there is no information in the display itself to bias an observer toward one interpretation or the other, in a majority of trials the stream response is reported. However, when an auditory stimulus is added to the presentation at the moment of overlap, this tendency reverses and the bounce response becomes dominant.

We sought to determine if the bounce/stream illusion is due to a perceptual or post-perceptual effect. 64-channel EEG plus two bipolar eye-movement channels were used to record continuous EEG while participants viewed visual-only (VO) and audio-visual (AV) bounce/stream displays plus an additional audio-only control. All the stimuli were in pseudo-randomized order with jittered inter-stimulus intervals. Continuous EEG data were epoched around stimulus onset and sorted by condition (AV or VO) and response (Bounce or No Bounce). In the visual-only condition, a response-related difference between the averaged ERPs emerged approximately 100 ms after the overlap. In the audio-visual condition, a response-related difference emerged approximately 200 ms after the overlap. Differences with these latencies are consistent with a bottom-up perceptually-driven effect. However, within the first 75 ms after the visual stimulus onset (approximately 525 ms before the moving objects overlapped), a difference on occipital and parieto-occipital electrodes emerges across the two response types for both VO and AV stimuli. This differential response well before the actual overlap event suggests that the early visual response indicates a state of the neural networks involved in eventually disambiguating this ambiguous event. In this presentation, we will describe coherence differences across conditions and response types. The early effects suggest that the pre-perceptual brain state is critically responsible for the perceptual illusion. (Research supported by NIH/NIDCD DC008308.)

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DAY 1 - MONDAY

Temporal dynamics of sound-induced contrast enhancement

Sascha Tyll, Bjoern Bonath, Hans-Jochen Heinze, Toemme Noesselt

Otto-von-Guericke University Magdeburg

Combining information across modalities can affect sensory performance. Here we studied how auditory stimuli modulate behavioral performance to visual stimulus detection of higher or lower contrast and its temporal dynamics with event related potential (ERP) and event related magnetic fields (ERMF). We varied the contrast of visual stimuli (gabor gratings) and orthogonally the presence of a sound while subject perform a visual detection task and ignored any co-occurring sounds, that yielded no information about stimulus occurrence. Behaviorally, we found significantly higher detection performance for low intensity stimuli paired with sound, reflected by hit rate and d-prime, but no changes for high intensity stimuli paired with sound. Importantly, no change in response criterion (ß) could be observed suggesting that our finding reflects a 'true' enhancement of sensitivity. The ERPs/ERMFs grand-average signatures indicate that this multisensory integration process for low intensity stimuli is associated with early neural activations over parieto-occipital sensors/ electrodes. Our results indicate that this sound-induced visual contrast enhancement is associated with an early modulation of processing in putative unisensory cortex.

Neural correlates of peri-hand space re-sizing following tool use: A combined computational and in vivo study

Elisa Magosso [1], Andrea Serino [2], Mauro Ursino [1], Cristiano Cuppini [1], Giuseppe Di Pellegrino [2], Elisabetta Làdavas [2]

[1]Department of Electronics, Computer Science and Systems, University of Bologna
[2]Cognitive Neuroscience Study and Research Center, University of Bologna

The peripersonal space may be considered as the action space within which the body directly interacts with external objects. There is converging evidence that peripersonal space is represented by a specialized circuit of multimodal neurons integrating tactile stimuli applied on a body part with visual stimuli delivered near the same body part, e.g. the hand. Tools used to extend the action space may modify the boundaries of the peri-hand area, where vision and touch are integrated. In extinction patients, a far visual stimulus at the tip of a right-held tool produces left tactile extinction similar to a near visual stimulus at the hand, only after the patients have used the tool to reach the far space. The neural mechanisms underlying such plasticity have not been yet identified. To this aim, neural network modeling may be integrated with the experimental research.

In this work, we pursued two main objectives: i) to use an artificial neural network in order to postulate some physiological mechanisms for peri-hand plasticity able to account for in-vivo data; ii) to validate the artificial network by testing predictions derived from simulations with an ad hoc behavioural experiment on an extinction patient.The model assumes that the modification of peri-hand space arises from a Hebbian growing of visual synapses converging into the multimodal area, which extends the visual RF of the peripersonal bimodal neurons. Under this hypothesis, the model is able to interpret and explain controversial results in the literature on peri-hand space reconfiguration, ascribing different results to different tool-use tasks during the learning phase. Importantly, model hypothesis implies that, after tool-use, re-coding of a far visual stimulus as a near one should be observed in vivo, even in absence of any physical connection between the subject's hand and the far space. This prediction has been validated experimentally

on a right brain damaged patient with visuo-tactile extinction. Before tool use, a visual stimulus near the right hand induced much more left tactile extinction than a far stimulus; after few minutes of tool use, the amount of visual-tactile extinction at the far location was similar to that at hand location, suggesting an extension of the integrative peri-hand space. Crucially, this effect was analogous both when the patient passively held the tool in her right hand, and when the tool was removed. Computational and experimental results of this study may provide important contribution to gain a deeper insight into the neural and functional mechanisms of peripersonal space representation and its plasticity. This work demonstrates how neural network modelling and simulations may integrate with experimental studies, by generating new predictions and suggesting novel and fruitful experiments to investigate cognitive processes.

A Crossmodal Müller-Lyer Illusion

Flavia Mancini, Emanuela Bricolo, Giuseppe Vallar

University of Milano-Bicocca

Arrows placed at the ends of a line may affect its estimated length. These illusions (Müller-Lyer and its variants) are equally powerful in vision and touch, although it is still unclear whether the visual and haptic illusory effects are due to modality-specific or shared processes.

In order to investigate the hypothesis of a common underlying mechanism, a manual bisection task of the Judd variant of the Müller-Lyer figure was administered to 24 undergraduate participants under visual, haptic, and visuo-haptic presentations (Experiment 1). In the bimodal condition participants saw the arrowheads on the front, and touched the shaft on the back of a stimulus-supporting board. We then replicated the bimodal task of Experiment 1 in another group of 20 undergraduate participants, manipulating the spatial position of the horizontal shaft on the backside of the board (Experiment 2). Illusory effects were comparable in touch and vision, and were present, albeit reduced, in the bimodal visuo-haptic condition. The visual arrowheads affected haptic bisection, only when the shaft was aligned with them. In conclusion, illusory effects transfer cross-modally from vision to haptics depending on the spatial coincidence of the visual and haptic components of the figure.

In search of an efferent rule in multisensory binding

Nina Jahn, Kielan Yarrow

City University

How does the brain match corresponding inputs across sensory modalities? Neurophysiological and behavioural studies have suggested that multisensory integration is facilitated by spatial and temporal overlap between inputs (the so called spatial and temporal rules). These rules are sensible, because both cues suggest strongly that the multimodal signals arise from a single cause. A similar inference is reasonable when we ourselves produce an action which causes reafferent feedback in two or more sensory modalities, as when we bang a drum. This observation suggests the possibility of an efferent rule for multisensory integration. We sought experimental evidence for the existence of such a rule. Experiment 1 made use of temporal order adaptation, the tendency for observers to adapt to a multimodal temporal asynchrony following repeated presentations. We predicted that adaptation should be greater for adapting stimuli that could be reliably paired based on efferent information. 18 participants adapted to three asynchronies (0, -200, +200 ms) of a spatially overlapping sound-light pair, and were tested in occasional temporal judgement trials to assess how their points of subjective simultaneity changed. Causality was manipulated in three conditions (causal: button press produces stimulus pair after a short, constant delay; non-causal: button presses are made, but dissociated from the stimulus pair using a longer variable delay; control: No button presses, just stimulus pairs). Simultaneity judgements revealed reliable adaptation, with a similar but non-significant trend in order judgments, but adaptation did not differ across the three experimental conditions, providing no evidence for an efferent rule. Two further experiments assessed multisensory binding more directly, by measuring the variability of judgements about temporal order and simultaneity in response to sound-light pairs coming from the same or different spatial locations. In line with previous results, judgements were more uncertain when stimuli came from the same spatial location, consistent with the stimuli having been combined into a single event. However, we were unable to demonstrate a similar effect when comparing pairs occurring after a key press with those arising at a predictable time but without a preceding action, at least when possible confounds were considered. Hence our search for evidence of an efferent rule in multisensory binding has not yet yielded positive results.

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DAY 1 - MONDAY

Cortical motor activity modulated by vision of the hand

Pascale Touzalin-Chretien, André Dufour

CNRS

Behavioral studies have employed various types of experiment to investigate the links between vision and proprioception, and there is a good deal of evidence to suggest that these two sensory modalities participate in visuomotor abilities. Neurophysiological studies have shown that activity in the primary motor cortex (MI) can be modulated either by illusory or imagined movements or by visual signals of hand movements. What remains to be resolved is whether the sole image of the hand is sufficient to elicit MI activation or if vision of the movement is necessary. Here we examined whether visual feedback from one hand can modulate the activity of the primary motor cortex, even when visual guidance of the hand is not necessary to perform the motor task. In our experimental setup, motor cortical activity was measured using the lateralized readiness potential (LRP), a cortical motor potential generated partially in MI, when subjects had to press a button with the right or left hand, which was either seen or not. We found that the LRP amplitude differed significantly between the two conditions, suggesting that visual feedback from the image of the hand is sufficient to modulate activity of MI. This may reflect the involvement of bimodal cells in the premotor cortex and their possible action on motor programming and/or execution.

Areal heterogeneity of bimodal neurons

M. Alex Meredith, Leslie P Keniston, Brian L Allman

Virginia Commonwealth University School of Medicine

Bimodal neurons have long been regarded as the basic unit of multisensory processing. Largely from studies of the superior colliculus (SC), bimodal neurons have been shown to integrate information from different sensory modalities. Also, features of the evoking stimuli influence the level of interaction achieved in all bimodal neurons, but different bimodal neurons exhibit different ranges of integrative capacity, or functional modes. Given that bimodal neurons also occur in cortex, it has been assumed (and questioned) that cortical neurons integrate multisensory information in the manner identified in the SC. Using the same methodology as in investigations of the SC, the present study examined the range of multisensory integration observed in bimodal neurons from 3 different feline cortical areas: Anterior Ectosylvian Sulcus (AES), Rostral Suprasylvian Sulcus (RSS), and the Posterolateral Lateral Suprasylvian area (PLLS). Both statistical and summative criteria for integration were used to define multisensory interactions. Unlike the SC, each cortical area revealed that less than 50% of the bimodal neurons generated statistically significant levels of integration, and even fewer (<20%) showed summative responses. In particular, bimodal neurons in RSS and PLLS were highly non-integrative. These results indicate that the multisensory properties of the SC and cortex are dissimilar and that the integrative capacity of a specific region is likely to be determined by the integrative range of its constituent neurons.

Multisensory processing in children with autism: high-density electrical mapping of auditory-somatosensory integration

Natalie Russo, John J Foxe, Hilary Gomes, Alice Brown, Ted Altschuler, Sophie Molholm

City College of New York

Purpose of the study: Successful integration of signals from the various sensory systems is crucial for normal sensory-perceptual functioning, allowing for perception of coherent objects rather than a disconnected cluster of fragmented features. Several prominent theories of autism suggest that automatic integration is impaired in this population, but there have been very few empirical tests of this thesis.

Method: A well-characterized electrophysiological metric of multisensory integration was used to test the integrity of auditory-somatosensory integration in children with autism (N=13, aged 6 to 14), compared to age and IQ matched typically developing children. High-density electrophysiology was recorded while participants were randomly presented with either auditory or somatosensory stimuli alone (i.e. unisensory presentations), or as a combined auditory-somatosensory stimulus. Participants watched a silent movie during testing, ignoring the concurrent stimulation.

Significant differences between neural responses to the multisensory auditory-somatosensory stimulus and the unisensory stimuli (the sum of the responses to the auditory and somatosensory stimuli when presented alone) served as the dependent measure of multisensory integration.

Results: These data indicate group differences in the integration of auditory and somatosensory information that appear relatively early in sensory processing, and are characterized by the presence of MSI for the TD but not the ASD children. Specifically, MSI was seen starting at about 100 ms in the control group, but only emerged starting at about 250 ms in the ASD group. In contrast, there were no group differences in the early sensory processing of the auditory and somatosensory stimuli when presented alone, demonstrating typical processing of the unisensory stimuli.

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Discussion: These findings are discussed within the framework of current knowledge of multisensory integration in typical development as well as in relation to theories of ASD.

DAY 1 - MONDAY

Multisensory Feature Integration: Does Pre-attentive Visual Object Processing Modulate the Cross-Sensory Spread of Attention?

Ian C. Fiebelkorn [1], John J. Foxe [1], Adam Snyder [2], Daniella Blanco [2], Theodore H. Schwartz [3], Sophie Molholm [1]

[1]City College of New York / Nathan Kline Institute
[2]City College of New York, [3]Weill Cornell Medical College

Focal spatial selection is a prerequisite for feature integration, but objects overlap in space, so there must be a process for object-based selection that also precedes feature integration. Segmentation of a visual scene, like what occurs during the formation of illusory contours, represents an obvious first step in the assignment of features to a common object. It is unknown, however, whether such pre-attentive visual object processing influences multisensory feature integration.

That is, does differential segmentation of a visual scene, which modulates visual object processing, also modulate multisensory feature integration? We used both scalp- and subdural-recorded event-related potentials to investigate whether the segmentation of a visual stimulus that results from the formation of illusory boundaries modulates the spread of attentional processing from an attended visual stimulus to a task-irrelevant tone. Such spreading of attentional processing is thought to reflect the binding of an object into a coherent whole. Participants viewed Kanizsa-type illusory contour and non-illusory contour stimuli and performed a visual task that was independent of the configuration of the inducers. Our results demonstrate that positioning the inducers to form illusory contours (i.e., a more coherent object with less ambiguous boundaries) indeed leads to enhanced processing of the paired task-irrelevant tone. We discuss our results in the context of a model for feature integration where (1) the visual boundaries of an object are established through processing in occipitotemporal cortex, and (2) attention then spreads through interactions with the posterior parietal cortex to cortical areas that process features within the object's now established visual boundaries, including task-irrelevant multisensory features.

KEYNOTE ADDRESS

2:00–3:00

Melding of minds: Combination of sensory cues improves spatial perception

Prof. Dora Angelaki

Washington University

A fundamental aspect of our sensory experience is that information from different modalities is often seamlessly integrated into a unified percept. Recent computational and behavioral studies have shown that humans combine sensory cues according to a statically optimal scheme derived from Bayesian probability theory; they perform better when two sensory cues are combined. We have explored multisensory cue integration for self-motion (heading) perception using both visual (optic flow) and vestibular (linear acceleration) signals. We recorded from single neurons in the dorsal medial superior temporal area (MSTd) of visual cortex during a heading discrimination task where trained monkeys, like humans, behaviorally combine visual and vestibular cues to improve heading perception. Under bimodal stimulation, MSTd neurons combine visual and vestibular cues linearly but sub-additively. Neurons with congruent heading preferences for visual and vestibular stimuli show improved sensitivity and lower neuronal thresholds under cue combination. In contrast, neurons with opposite preferences show diminished sensitivity under cue combination. We further show that MSTd responses are significantly correlated with the monkeys' perceptual decisions in a congruency-dependent manner. Deficits in behavior brought by chemical inactivation of this area provide further support of the hypothesis that extrastriate visual cortex mediates multisensory integration for self-motion perception. These findings provide the first behavioral demonstration of statistically-optimal cue integration in non-human primates and identify a population of neurons that may form its neural basis.

Oral Session 1: Attention

3:00 – 4:00

3:00 – 3:20

Attentional influences on multisensory processing

Marty G. Woldorff

Duke University

As well recognized in this conference, a critical task in daily life is the accurate perception and integration of information from multiple sensory modalities. Although some earlier studies had suggested that the interactions and integration of multisensory information consisted of mostly lower-level automatic processes, various more recent studies have indicated that attention can have a substantial modulatory influence over multisensory processing interactions. These attentional influences on multisensory interactions have been shown to include effects on the processing of audiovisual stimulation whose audio and visual components occur at the same location with synchronous or near-synchronous timing. In addition, however, it has recently been shown that attention to stimuli in one modality (vision) can spread to irrelevant but synchronous stimuli in another modality (audition), even when these stimulus components arise from different spatial locations (e.g., during ventriloquistic circumstances). In this talk, some of these recent studies showing how attention can influence multisensory processing, and how it can spread across the individual components of a multisensory stimulus, will be discussed, along with what these findings tell us about the mechanisms of both attention and multisensory processing.

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Oral Session 1: Attention

3:20 – 3:40

Competition for attentional resources between auditory and visual spatial cues

Thomas Koelewijn [1], Adelbert Bronkhorst [1, 2], Jan Theeuwes [1]

[1]Vrije Universiteit Amsterdam, [2]TNO Human Factors

Already more then a decade ago it was shown that sound can capture our visual attention. However, there is still debate as to whether this auditory capture effect is a fully automatic process. Recent studies show that when visual endogenous attention is focused to a predefined target location sound is still able to capture attention. Because of these findings it has been argued that auditory stimuli can automatically capture visual attention. However, capture is only truly automatic when it is not only insensitive to top-down information but also to competing bottom-up information. Therefore, the current study investigated whether there is interaction between exogenous auditory and visual capture. Participants performed an orthogonal cueing task in which the visual target was preceded by peripheral visual and auditory cues (see Figure 1a). The auditory cue consisted of a white noise burst that was shortly presented through one of the speakers located at the left or right side of the computer screen. We simultaneously presented a peripheral visual cue in the form of an onset. The auditory and visual cues were independently valid or invalid with respect to the target location. In Experiment 1 the visual cue was exogenous since it was valid at chance level (50%). In Experiment 2 the visual cue was predictive since it indicated with a high probability the likely target location (validity 80%). The auditory cue was unpredictive at 50% validity in both experiments. Experiment 1 (Figure 1b) showed both auditory and visual cueing effects, which indicates that auditory capture is not prevented when a competing exogenous visual event is presented. The results of the second experiment (Figure 1c) show no auditory cueing effect. These results demonstrate that auditory capture does not occur when a predictive peripheral visual event is presented at the same time. Based on these outcomes we conclude that attentional capture by sound is not a fully automatic process.

DAY 1 - MONDAY

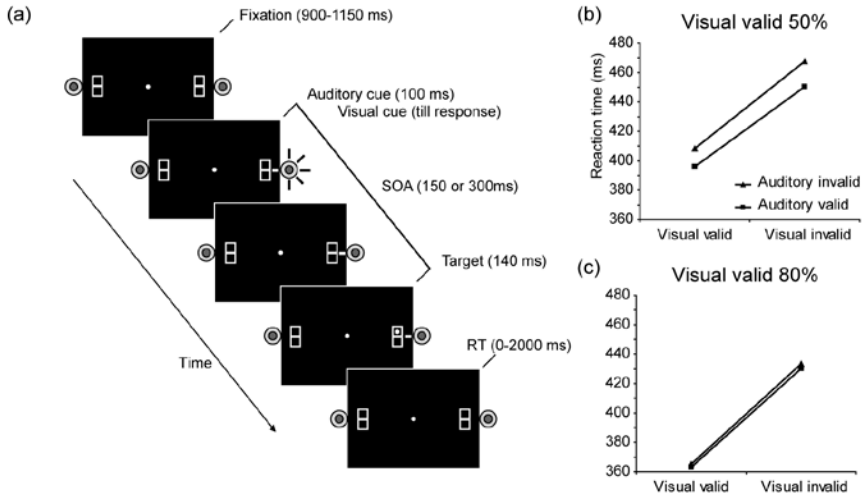

Figure 1. (a) A schematic representation of the paradigm. (b) The results when both visual and auditory cues were presented at chance level. (c) The results when the visual cue was 80% valid and the auditory cue was presented at chance level.

Oral Session 1: Attention

3:40 – 4:00

Redundant target or focused attention: Two different paradigms but the same crossmodal integration mechanism?

Adele Diederich [1], Hans Colonius [2]

[1]Jacobs University Bremen, [2]Institut für Psychologie, Carl von Ossietzky Universität Oldenburg

Two different experimental paradigms are used to measure reaction time (RT) to a crossmodal stimulus set. In the redundant target (aka divided-attention) paradigm, stimuli from different modalities are presented simultaneously or with certain stimulus onset asynchrony (SOA), and the participant is instructed to respond to the stimulus detected first. Typically, the time to respond in the crossmodal condition is faster than in either of the unimodal conditions. In the focused attention paradigm, crossmodal stimulus sets are presented in the same manner but now, participants are instructed to respond only to the onset of a stimulus from a specifically defined target modality, such as the visual, and to ignore the remaining non-target stimulus, the tactile or the auditory, say. In the latter setting, when a stimulus of a non-target modality, a tone, say, appears before the visual target, there is no overt response to the tone if the participant is following the task instructions. Nevertheless, the non-target stimulus has been shown to modulate the saccadic response to the target. The distinction between the redundant target and the focused attention paradigm is not only an interesting experimental variation as such, but it may also provide an important theoretical perspective. In fact, since the stimulus setup can be chosen to be identical in both paradigms, any differences observed in the responses would have to be due to the instructions only. Here we show how the time-window-of-integration (TWIN) model developed by the (Colonius & Diederich, JCogNeurosci 2004; Diederich & Colonius, BrainRes 2008) accounts for such results.

Oral Session 1: Attention

4:00 – 4:20

Explaining the Colavita Visual Dominance Effect

Charles Spence [1], Cesare Parise [2], Yi-Chuan Chen [1]

[1]University of Oxford, [2]Università degli Studi di Trento

The last couple of years have seen a resurgence of interest in the Colavita visual dominance effect. In the basic experimental paradigm (Colavita, 1974), a random series of auditory, visual, and audiovisual stimuli are presented to participants who are instructed to make one response whenever they see a visual target and another response whenever they hear an auditory target. Many studies have now shown that participants sometimes fail to respond to auditory targets when they are presented at the same time as visual targets (i.e., on the bimodal trials), despite the fact that they have no problems in responding to the auditory and visual stimuli when they are presented individually. The existence of the Colavita visual dominance effect provides an intriguing contrast with the results of the many other recent studies showing the superiority of multisensory (over unisensory) information processing in humans. Various accounts have been put forward to try and explain the effect, including the suggestion that it reflects nothing more than an underlying bias to attend to the visual modality. In this presentation, the empirical literature on the Colavita visual dominance effect is reviewed, and some of the key factors modulating the effect highlighted. The available research has now provided evidence against all previous accounts of the Colavita effect. We put forward a novel explanation of the Colavita effect, based on the latest findings highlighting the asymmetrical effect that auditory and visual stimuli exert on people's responses to stimuli presented in the other modality (see Sinnett et al., 2008).

References

Colavita, F. B. (1974). Human sensory dominance. Perception & Psychophysics, 16, 409-412.

Sinnett, S., Spence, C., & Soto-Faraco, S. (2008). The co-occurrence of multisensory competition and facilitation. Acta Psychologica, 128, 153-161.

Symposium 2: New insights into crossmodal plasticity

5:00 – 7:00

Organised by Alex Meredith

Chair: Alex Meredith

Speakers:

Susan Shore, *Kresge Hearing Research Institute, University of Michigan Medical School*

Brian Allman, *Virginia Commonwealth University*

Steve Lomber, *Centre for Brain and Mind, University of Western Ontario*

Gary Paige, *University of Rochester*

Overview: It has been 25 years since the seminal work of Rauschecker and Korte that essentially forged the field of crossmodal plasticity. Since then, a great deal has been learned about the mechanisms of neuronal plasticity that have brought into question some of the popularly held notions derived from this classical work. Specifically, crossmodal plasticity has also become synonymous with 'adaptive' or 'compensatory' plasticity, but recent work from Steve Lomber's lab has shown that only a subset of modality-specific processing features may be augmented by this process. Similarly, it has been asserted that crossmodal plasticity is the pervue of the cerebral cortex, but Susan Shores' work has now demonstrated that crossmodal reorganization occurs at multiple sites in the brainstem. Furthermore, although the effects of crossmodal plasticity are largely manifest after early sensory lesions, Brian Allman and Alex Meredith have shown that massive crossmodal reorganization of auditory cortex occurs following deafening in adult animals. Finally, Gary Paige's investigations show that crossmodal re-calibrations occur relative to motor programs over a lifetime.

These conceptual shifts have clinical relevance: given that hearing impairment in adults is among the most prevalent neurological disorders in man, these data indicate that crossmodal plasticity could play a profound role in sensory perception and disorders in a very large number of individuals. Therefore, it is an appropriate time to re-evaluate the fundamental issues of crossmodal plasticity, but with respect for that which has brought the field to this point.

Symposium 2: New insights into crossmodal plasticity

Crossmodal Plasticity: not just for cortex any more

Susan E Shore, Ph.D.

Kresge Hearing Research Institute,
University of Michigan Medical School

A feature of multisensory neurons is their capacity for crossmodal innervation following sensory deprivation. Multisensory neurons in the dorsal cochlear nucleus receive auditory input via VIIIth nerve fibers as well as somatosensory input via the axons of cochlear nucleus granule cells. This pattern of convergence would suggest that reduction of VIIIth nerve input to the cochlear nucleus would result in compensatory innervation via the somatosensory input systems, one of which is trigeminal. Comparison of DCN responses to trigeminal and bimodal (trigeminal plus acoustic) stimulation in normal and noise-damaged guinea pigs showed that the latter had significantly lower thresholds, shorter latencies and durations, and increased amplitudes of response to trigeminal stimulation than normal animals. Noise-damaged animals also showed a greater proportion of inhibitory and a smaller proportion of excitatory responses compared with normal. The number of cells exhibiting bimodal integration, as well as the degree of integration, was increased after noise damage. These results indicate that projections from the trigeminal system to the cochlear nucleus are amplified and reorganized after hearing loss, and point to crossmodal reorganization of this major brainstem sensory nucleus.

Symposium 2: New insights into crossmodal plasticity

Crossmodal Plasticity: not just for juveniles any more

Brian L. Allman, Ph.D.

Virginia Commonwealth University

Crossmodal reorganization, a phenomenon whereby the responsiveness of a sensory area is converted from a deprived modality to that of an intact sensory system, commonly occurs in response to developmental lesions. However, little is known about its capacity for crossmodal remodeling in the adult brain. In this context, the potential for cortical crossmodal reorganization was examined in ferrets deafened as adults. Recordings from adult-deafened 'auditory' cortex revealed an extensive conversion: neurons once activated by auditory cues were now driven by somatosensory stimulation. This effect was observed within 16 days of deafness. Recordings from hearing animals indicated that subthreshold somatosensory inputs were insufficient for their unmasking, by deafness, to account for the observed conversion. Lack of change in anatomical connectivity suggests that the crossmodal conversion may be reflective of reorganization elsewhere in the auditory pathway, such as has been demonstrated in the brainstem of hearing impaired animals. Collectively, these data demonstrate that significant cortical crossmodal reorganization can occur after the period of sensory system maturation has ended.

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Symposium 2: New insights into crossmodal plasticity

Crossmodal Plasticity: what is compensatory and what is not?

Stephen G. Lomber, Ph.D.

Centre for Brain and Mind, University of Western Ontario

When the brain is deprived of input from one sensory modality, it often compensates with supernormal performance in one or more of the intact sensory systems. In the absence of acoustic input, it has been proposed that "deaf" auditory cortex may be recruited to perform visual functions. To test this hypothesis we examined the visual capabilities of congenitally deaf cats (and hearing controls) on a battery of visual tasks to define which visual abilities are affected by cross-modal compensation. For tests of grating acuity, Vernier acuity, direction of motion discrimination, velocity discrimination, and orientation discrimination performance in the deaf cats was similar to that of hearing cats. However, for two tests (movement detection and localization of a flashed stimulus) the deaf cats demonstrated superior performance to that of the hearing cats. To determine if crossmodal reorganization in auditory cortex contributes to the superior visual capabilities of deaf cats, we bilaterally placed cooling loops on A1, DZ, AAF, and PAF to permit their individual deactivation. Deactivation of neither A1, nor AAF, altered performance on either the movement detection or visual localization tasks. However, bilateral deactivation of PAF resulted in the elimination of the superior visual localization capabilities of the deaf cats and resulted in performance similar to hearing cats. Furthermore, bilateral deactivation of DZ resulted in the elimination of the superior movement detection capabilities of the deaf cats and resulted in performance similar to hearing cats. Therefore, the results demonstrate a double dissociation, with superior visual localization abilities mediated by PAF and superior movement detection abilities mediated by DZ. These observations establish that enhanced visual performance in deaf cats is caused by cross-modal reorganization within "deaf" auditory cortex and that it is possible to localize and dissociate individual visual functions within reorganized auditory cortex.

DAY 1 - MONDAY

Symposium 2: New insights into crossmodal plasticity

Crossmodal Plasticity: not just sensory, but sensorimotor

Gary D. Paige, MD, Ph.D.

University of Rochester

Vision and audition each provide the brain with spatial representations of the external world. The coherence and integration of these maps requires that the two senses maintain spatial calibration (gain and alignment). Two key challenges arise. 1) While vision encodes spatial input directly and topographically onto the retina, auditory space must be constructed *centrally* based upon interaural and spectral cues from the two ears. 2) The reference frames of visual and auditory space (oculo- and head-centric, respectively) shift alignment during eye movements, and the brain must accurately account for this to maintain register and space constancy, using an eye-in-head signal. The brain largely solves these problems despite changes due to development, disease, and senescence through adaptive plastic mechanisms that maintain cross-sensory calibration given adequate interactive experience, and other processes that include genetic (e.g. during development) and adaptation phenomena independent of learning.

We have addressed different forms of adult adaptation phenomena that are responsible for maintaining visual-auditory spatial calibration and space constancy. Experiments have demonstrated adaptive plasticity of both auditory spatial gain and alignment in response to optical manipulations (magnifying lenses and prisms) as well as their equivalents applied directly to auditory input by way of a novel pseudophone technique. We have also quantified the influence of eye position on sound localization, and other spatial variables, that act independently and without cross-sensory plasticity. Both adaptive experience-dependent sensori-motor learning and other adaptation factors combine to integrate the spatial senses and ultimately to guide natural spatial behavior over a lifetime.

Day Two

Tuesday June 30th 2009

8:30 –9:00	**Registration**
9:00 –10:30	**Posters II (coffee/snack)**
10:30 –12:30	**Symposium 3: An embodied view of multisensory speech - Chaired by Asif Ghazanfar**
12:30 –1:30	**Light lunch – wraps and bevgs**
1:30 –3:30	**Symposium 4: Graduate student award talks**
3:30 -4:30	**Keynote 2 – Jon Kaas**
4:30 –5:30	**Oral Session 2: Body schema**
5:30 –7:30	**BBQ style food and beer on campus**

POSTERS II
June 30th 2009
09:00 – 10:30

Evaluating the Effectiveness of Temporally Synchronous and Spatially Predictive Cues in Visual Search

Mary Kim Ngo, Charles Spence

University of Oxford

The presentation of spatially predictive auditory cues can reduce visual search times for targets presented in the central visual field (Perrott et al., 1990). Spatially-nonpredictive auditory or tactile cues have also been shown to facilitate visual search when their presentation is synchronized with that of the target (Fujisaki et al., 2006; Van der Burg et al., 2008; Van der Burg et al., 2009). To date, researchers have either looked at the effect of temporal synchrony or at the effects of spatial coincidence on visual search performance singularly, but never both at the same time. The present study was therefore designed to explore how the temporal synchrony and/or spatial coincidence of auditory cues would modulate visual search performance. Participants searched for a horizontal or vertical line segment among distractor line segments, all of which regularly changed colour (our experimental design was based on Van der Burg et al.'s, 2008, "pip and pop" experiments). In separate conditions, the auditory cues were temporally synchronized with the target colour change and spatially informative regarding the hemifield in which the target where the target was presented. The results showed that the presentation of the auditory cue led to a significant facilitation of search times relative to performance in a no auditory cue baseline condition. Although search times were slightly faster when the auditory cue was both temporally synchronized and spatially informative than when it was temporally synchronized but spatially uninformative, this difference was not significant. Thus, it appears that the benefit attributable to the presentation of a temporally synchronous auditory cue is not augmented by making it spatially informative, at least when the visual search field is relatively small and the auditory cues are presented over headphones. Given that Bolia et al. (1999) have shown that the benefits of spatially informative auditory cues are greater when presented in the free-field as compared to when they are presented over headphones, we will also report on the results of additional experiments in which the auditory cues were presented from external loudspeakers co-localized with the visual search display. Finally, we will compare the magnitude of the facilitation effects following auditory versus tactile cuing. We will also highlight the relevance of these results for research in the applied domain.

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Fujisaki, W., Koene, A., Arnold, D., Johnston, A., & Nishida, S. (2006). Visual search for a target changing in synchrony with an auditory signal. Proceedings of the Royal Society B: Biological Sciences, 273, 865-974. Perrott, D. R., Saberi, K., Brown, K., & Strybel, T. Z. (1990). Auditory psychomotor oordination and visual search performance. Perception & Psychophysics, 48, 214-226.

Van der Burg, E., Olivers, C. N. L., Bronkhorst, A. W., & Theeuwes, J. (2008). Pip and pop:nonspatial auditory signals improve spatial visual search. Journal of Experimental

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DAY 2 - TUESDAY

Multisensory attentional-spread activity reveals tighter audiovisual-synchrony constraints for the spatial shifts of ventriloquism than for the temporal linking of auditory and visual events

Sarah E. Donohue, Maria A. Pavlova, Kenneth C. Roberts, Tineke Grent-'t-Jong, Marty G. Woldorff

Duke University

A fundamental task in daily life is the accurate perception and integration of information from multiple modalities into discrete objects. This can be done in a robust and reliable manner by using cues from space and time, with stimuli more proximal in space and/or time more likely to be arising from the same object and thus needing to be linked together and integrated. On the other hand, auditory and visual stimuli can be temporally linked together when they occur within a relatively wide temporal window of integration, and during the ventriloquism illusion the spatial location of an auditory stimulus can be perceptually drawn toward that of a simultaneously occurring visual stimulus. Attention appears to play a key role in these processes by aiding in the grouping of sensory information, whether it be within a single modality or across modalities. Moreover, it has been shown that attention to stimuli in one modality (vision) can spread to irrelevant but synchronous stimuli in another modality (audition), even when they arise from different locations, an effect reflected by a late (>200 ms), long-lasting (200-700 ms) frontal ERP negativity and an enhanced level of auditory-cortex fMRI activity (Busse et al., 2005).

Using EEG in 18 healthy participants, we investigated such attentional spread when the irrelevant auditory event was either physically simultaneous with the visual, delayed by 100 ms (inside the temporal window of integration), or delayed by 300 ms (outside the temporal window of integration), with all cases having spatial separation between the auditory and visual stimuli. When the irrelevant auditory stimulus was synchronous with an attended versus an unattended visual event, the late frontal negativity was enhanced, replicating Busse et al. (2005). When the auditory stimulus was delayed by 100 ms, the main sustained part of late frontal negative wave was slightly attenuated relative to the simultaneous condition, and shifted in time by 100 ms.

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When the auditory stimulus was delayed by 300 ms, the late negative wave was highly attenuated and shifted by 300 ms. Further, when the auditory and visual stimuli occurred simultaneously, the attentional spread ERP activity began with an additional fronto-central negative-wave component at 200 ms, an activation that was not seen in the 100-ms or 300-ms delay conditions. This initial negative component occurred contralateral to the side of the attended visual stimulus, likely reflecting the neural underpinnings of the perceptual shift in the spatial location of the sound toward that visual stimulus. This effect was similar in timing and distribution to that observed by Bonath et al., 2007; here, however, it was only found as a function of multisensory attention (i.e., from the difference wave between conditions when the auditory stimulus occurred with an attended versus an unattended visual event). In contrast, the more sustained, noncontralateral, negative-wave activity elicited for both the simultaneous and the 100-ms delay conditions appears to be reflective of the multisensory temporal linking than can take place for visual and auditory events that occur across a broader time window. These results provide novel insight into the temporal and spatial linking of the unisensory components of multisensory stimuli, and the way in which attention interacts with these perception-related stimulus-linking processes.

DAY 2 - TUESDAY

Adaptation to audiovisual asynchrony modulates the speeded detection of sound

Jordi Navarra [1], Jessica Hartcher-O'Brien [2], Charles Spence [2]

[1]*Fundació Sant Joan de Déu, Hospital Sant Joan de Déu*
[2]*University of Oxford*

The brain adapts to asynchronous audiovisual signals by reducing the subjective temporal lag between them. However, it is currently unclear which sensory signal (visual or auditory) shifts toward the other. According to the idea that the auditory system codes temporal information more precisely than the visual system, one should expect to find some temporal shift of vision toward audition (as in the temporal ventriloquism effect) as a result of adaptation to asynchronous audiovisual signals. Given that visual information gives a more exact estimate of the time of occurrence of distal events than auditory information (due to the fact that the time of arrival of visual information regarding an external event is always closer to the time at which this event occurred), the opposite result could also be expected. Here we demonstrate that participants' speeded reaction times (RTs) to auditory (but, critically, not visual) stimuli are altered following adaptation to asynchronous audiovisual stimuli. After receiving "baseline" exposure to synchrony, participants were either exposed to auditory-lagging asynchrony (VA group), or to auditory-leading asynchrony (AV group). The results revealed that RTs to sounds became progressively faster (in the VA group) or slower (in the AV group) as participants' exposure to asynchrony increased, thus providing the first empirical indication that speeded responses to sounds are influenced by exposure to audiovisual asynchrony.

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Aurally aided visual search in depth using 'real' and 'virtual' crowds

Jason S Chan, Simon Dobbyn, Paul McDonald, Henry J Rice, Carol O'Sullivan, Fiona N Newell

Trinity College Dublin

It is well known that a sound presented at the same location on the horizontal plane as a visual target can improve the detection of the target by guiding attention to that location (Perrott, Cisneros, McKinley, & D'-Angelo, 1996; Spence & Driver, 1996). We asked whether sound can affect search for a visual target presented in different depths. In separate experiments, we explored aurally aided visual search in 3-dimensional space using 'real' and 'virtual' environments. In Experiment 1, our visual scene consisted of an array of eight face images presented as an array of 4 faces images in a near horizontal location (i.e. within peripersonal space) and 4 images located in a far horizontal location. Each face image was paired with a loudspeaker. The participant's task was to indicate whether the visual target face which was indicated by a flash of an LED light, was either 'near' or 'far'. Sounds were presented simultaneously with the LED light but were either congruent or incongruent with the location of the target. In Experiment 2, we presented virtual scenes of people and the participant's task was to locate a target individual in the visual scene. Congruent and incongruent virtual voice information, containing distance and direction location cues, were paired with the target. In both Experiments, we found that response times were facilitated by a congruent sound. Our findings suggest that sound can have a significant influence on locating visual targets presented in depth in both real and virtual displays and has implications for understanding crossmodal influences in spatial attention and also in the design of realistic virtual environments.

DAY 2 - TUESDAY

Audiovisual speech integration is modulated by the interpretation of the auditory stimuli: An ERP study

Jeroen Stekelenburg, Jean Vroomen

Tilburg University

Tuomainen et al. (Cognition, 2005) showed that the interpretation of auditory stimuli affects audiovisual (AV) speech integration. Perceptually ambiguous sine wave replicas (SWS) of natural speech were presented to listeners who were in speech mode (participants were trained to perceive the SWS stimuli as speech) or non-speech mode (participants were not aware that the auditory stimuli were speech). Audiovisual speech integration (lipreading biasing audition) was only observed for listeners in speech mode. Here, we examined the neural correlates of this effect using the "McGurk mismatch negativity (MMN) paradigm". In an oddball sequence, 'standards' consisted of auditory /onso/ coupled with visual /onso/, and 'deviants' consisted of auditory /onso/ coupled with visual /omso/. A visual-only condition was run to rule out that the AV MMN was confounded by the visual part of the audiovisual deviant. Two groups, one in speech mode, the other in non-speech mode, were presented the SWS replicas of /onso/, while a third group heard the natural /onso/ speech token. The natural AV deviant induced the McGurk illusion triggering the automatic auditory change-detection system, as indexed by the MMN. For the SWS stimuli, an MMN was only evoked in the speech mode group (starting at about 180 ms), but not in the non-speech mode group. These results demonstrate that the modulation of audiovisual integration by the interpretation of the auditory stimuli takes place automatically at early sensory processing stages. Our study found evidence for the existence of a speech-specific multisensory mode of perception on the neural level.

Surface properties affect within-and cross-modal object recognition

Jenelle Hall, Simon Lacey, K Sathian

Department of Neurology, Emory University School of Medicine

Object recognition studies typically focus on shape rather than surface properties and have almost exclusively involved vision. Visual object recognition is impaired when surface properties, such as color, change between study and test, suggesting that these properties form part of the visual representation of the object (Nicholson & Humphrey, Perception 32:339-353, 2004). Cross-modal recognition of objects is hypothesized to rely on a modality-independent representation of shape but whether this representation also contains information about surface properties is unknown. Here, we manipulated the color and texture of objects to investigate their effect on visual and haptic within-modal and cross-modal object recognition (both visual-haptic and haptic-visual). In Experiment 1, changing the color schemes of objects impaired within-modal visual recognition but had no effect on either cross-modal condition or, unsurprisingly, on within-modal haptic recognition. In Experiment 2, we changed the texture schemes of objects. Changing the texture schemes impaired recognition in all conditions. This shows that surface properties may form part of haptic object representations, as previously shown for vision. The reduction in cross-modal recognition when textures changed suggested that the underlying modality-independent representation encodes surface properties. However, this result could also simply reflect a general disruptive effect of changes in modality-independent surface properties that was not present in Experiment 1. To address this, Experiment 3 examined the effect of texture and orientation changes. Because the modality-independent representation underlying cross-modal recognition is also view-independent (Lacey, Peters & Sathian, PLoS ONE, 2:e890, 2007), if texture changes reduced recognition but without affecting view-independence, this would indicate that the modality-independent representation also encodes surface properties. We found that cross-modal recognition was indeed impaired by changes in texture but not changes of orientation. We conclude that the modality-independent, view-independent object representation does contain information about modality-independent surface properties.

A relation between Pseudo-Haptic perception and preceding / delayed visual image

Tomoko Yonemura [1, 2, 3], Hiroki Kawasaki [1], Shin Okamoto [1], Hideyuki Ando [1], Taro Maeda [1]

[1]Osaka University, [2]JST, [3]CREST

Previous studies have shown that modifying visual information contributes to on-line manipulations of hand movements and that pseudo-force sensations can be induced by modifying speeds of the visual hand image (Le´cuyer, Coquillart, Kheddar, Richard & Coiffet, 2000; Puscha, Martinb & Coquillart, 2009). The Pseudo-Haptic is illusion in which participants perceive force by modifying (acceleration / deceleration) the visual feedback of their ongoing motions without any real physical haptic stimulation. This phenomenon occurs when the speed of their own hand image has been modified while they move hands. However it is not known whether the speed change of peripheral visual image can cause Pseudo-Haptic perception. Therefore, we investigate Pseudo-Haptic perception when two images of their own and a peripheral hand are shown simultaneously and either of the two hand images is preceding or delayed. The peripheral hand image moves keeping a constant distance to own hand image. In our experiments, the participants are asked to move own hand from a starting point to a goal, and to report the occurrence of Pseudo-Haptic under following 5 kinds of visual feedback with/without modifications, i.e., no change, accelerated / decelerated own/peripheral hand image. For the distance between their images, 7.7 (near condition) and 13.5 (far condition) degrees of the visual angle are used, which is decided from the range of the central visual field. As a result, we found that the peripheral hand image, which is not their hand image, can also induce the Pseudo-Haptic. Regarding to the occurrence rate, Pseudo-Haptic appeared more often in the near condition when modifying the peripheral hand image. Especially the deceleration of preceding and the acceleration of the delayed image more induced the illusion in the near condition. In the far condition, this phenomenon occurred only when a peripheral hand move closer to own one. Our findings suggest that the occurrence of Pseudo-Haptic is influenced by an object nearing own hand in the range of the central visual field. We also show that adjusting the position of the peripheral hand image can control the places where pseudo-force occurs in their arm. At the end, the integrated mechanism of visual and proprioceptive information will be discussed.

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DAY 2 - TUESDAY

Amodal central calculation system underlying visual and auditory expert adding performance: a case study

Yixuan Ku [1], Wenjing Zhou [2], Dan Zhang [1], Bo Hong [1], Xiaorong Gao [1], Shangkai Gao [1]

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Human neuroimaging studies have shown that intraparietal sulcus (IPS) could have a central amodal representation of quantity. However, experts' adding large numbers with many digits in very short time may not be simply in this way. An expert who has taken a long period of abacus training and been awarded many champions performed several adding tasks (with 8-digits and 4digits numbers either presented by a LED screen or played by speakers) in this study. Functional magnetic resonance imaging (fMRI) showed that in both visual and auditory adding tasks, bilateral superior parietal lobule (brodmann area 7) and middle frontal gyrus (brodmann area 40) were activated, compared with control tasks. Electroencephalography (EEG) topography on scalp also showed bilateral parietal and frontal activity at around 400ms after visual stimulus presented. Phase synchrony analysis indicated that the parietal and frontal brain areas collaborated with each other in alpha band and this connection was stronger in adding tasks than control tasks. This could be seen in both visual and auditory tasks. In conclusion, visual and auditory information converge to the same central system involving parietal and frontal loop which execute calculation process.

Assessing the effects of voluntary action on sensitivity to temporal asynchrony between auditory and somatosensory events

Norimichi Kitagawa [1], Masaharu Kato [2], Makio Kashino [1]

[1]NTT Communication Science Laboratories
[2]Doshisha University

When we actively interact with the environment, it is crucial that we perceive precise temporal relationship between our own actions and subsequent sensory effects to guide body movements. Despite its significance, however, little attention has been paid to the effects of voluntary action on temporal perception of sensory events. The present study examined how voluntary action affects the performance of temporal order judgment (TOJ) for pairs of auditory and somatosensory events. In the voluntary condition, participants actively pressed a button and a noise burst was presented at various onset asynchronies relative to the button press. The participants made either 'sound-first' or 'touch-first' responses. We found that the TOJ performance in the voluntary condition (as indexed by just noticeable difference) was significantly better than that when their finger was passively stimulated (passive condition). We further examined whether the performance improvement with voluntary action can be attributed to the predictability of the timing of the stimulation, the kinesthetic cues contained in the voluntary action, and/or the existence of the motor command. When three noise bursts were presented before the target burst with regular intervals (predictable condition) and when the participant's finger was moved passively to press the button (involuntary condition), the TOJ performance was slightly better than that in the passive condition, but the improvements failed to reach statistical significance. These results suggest that the improvement in sensitivity to temporal asynchrony between auditory and somatosensory events caused by the voluntary action cannot be fully attributed to sensory predictions and kinesthetic cues. Rather, the existence of the motor command and its efference copy would be crucial for improving temporal sensitivity.

Effects of tone-sequence frequency changes on visible persistence of apparently moving visual stimuli

Souta Hidaka [1], Wataru Teramoto [1, 2], Jiro Gyoba [1], Yôiti Suzuki [3]

[1]Graduate School of Arts and Letters, Tohoku University,
[2]Research Institute of Electrical Communication, Tohoku University,
[3]Research Institute of Electrical Communication, Tohoku University

In a visual apparent motion display, the visual duration (visible persistence) of a moving stimulus lasts longer than usual after its offset when the moving stimulus abruptly changes its attribute (size) (Moore et al., 2007). We investigated whether and how an abrupt change in an attribute of the contingent auditory stimuli can alter the visible persistence of the stimuli in apparent motion. The visible persistence extended longer when an abrupt change in frequency was introduced into a sequence of constant tones presented synchronously with apparently moving visual stimuli than when no abrupt change or no auditory information was introduced (Experiment 1). However, an abrupt onset of a tone burst or an abrupt offset in a sequence of tone bursts did not alter the visible persistence. These results proved that the results of Experiment 1 were not attributable to changes in the perceived intensity of the visual stimuli, attentional capture to the visual changes, or response biases induced by transient auditory signal (Experiments 2 and 3). Furthermore, the effect of an abrupt change in frequency on the visible persistence attenuated when the tones were difficult to attribute to the moving visual stimuli (Experiment 4). These results suggest that the object representations of moving visual stimuli might be formed through multisensory integration of visual and auditory information.

The timing of supramodal and unimodal spatial selection in a trial-by-trial cuing paradigm

Rob Henricus van der lubbe, Jurjen van der Helden

Dept. of Psychonomics, Utrecht University, Utrecht, The Netherlands

Previous ERP studies focusing on supramodal spatial selection effects with visual and auditory stimuli regularly used block wise manipulations of focused attention and frequently employed a between-subjects design in which participants had to attend to either visual or auditory stimuli. A potential disadvantage of a design in which only visual or auditory stimuli are relevant is a strong suppression of any modality-irrelevant stimulation, thereby potentially underestimating supramodal spatial selection effects. In the current study, participants were instructed to attend to either the left or right and to either auditory or visual stimuli. They had to press a button when a deviant target of the relevant modality was presented on the relevant side (5% of the stimuli). The instruction varied on a trial-by-trial basis, and was indicated by a directional cue accompanied with a word indicating the relevant modality. A train of four stimuli, separated by 1 s, was subsequently presented, of which the location and modality varied randomly. ERPs showed not only supramodal but also modality-specific effects within the cue-target interval preceding the four stimuli. The P1 component for visual stimuli and N1 component for auditory stimuli were enlarged when the stimuli occurred on the to-be-attended side, irrespective from the relevance of the visual or auditory modality, suggesting that attentional selection shifts from an initial supramodal to a modality-specific level.

Audiovisual category transfer in rodents

Antje Fillbrandt [1], Frank W Ohl [1, 2]

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A basic process in the build up of conceptual knowledge is the formation of categories involving the abstraction of shared features from the specific sensory experiences. Our previous work in the rodent (gerbil) auditory system has demonstrated that the formation of auditory categories is accompanied by the emergence of category-specific spatiotemporal activity patterns in auditory cortex (Ohl et al., Nature, 2001). Here, the investigation of the formation of category-specific activity patterns was extended to the multisensory domain. We have examined whether perceptual categories, after being formed in one sensory modality (audition or vision), can be transferred to another sensory modality (vision or audition, resp.), and have suggested a physiological basis for this audiovisual category transfer.

We trained Mongolian Gerbils (Meriones unguiculatus) to associate a slow (0.5 Hz) and a fast (5 Hz) presentation rate of stimuli with the Go response and NoGo response, respectively, in an active avoidance paradigm (shuttle box). One group of animals was trained with auditory tone pips, the other with visual flashes as stimuli. After sufficient training with the first sensory modality, a second training phase was initiated in which the sensory modality of the stimuli was changed from auditory to visual, or from visual to auditory, respectively. In this second training phase, groups were further split into a group with congruent training (contingency between presentation rate and required response remained unchanged) and a group with incongruent training (contingency between presentation rate and required response was reversed).

After the modality switch, the congruent groups showed a higher acquisition rate of the conditioned responses than the incongruent groups indicating a crossmodal transfer of the rate-response association.

During training, the electrocorticogram was recorded from two 16 -electrode arrays chronically implanted onto the epidural surface of primary auditory and the visual cortex. Cortical activity patterns in the ongoing electrocorticogram (ECoG) associated with the Go- and the No-Go stimuli were determined in the spatial distribution of signal power using a multivariate pattern classification procedure (Barrie et al., J. Neurophysiol., 1996; Freeman, J. Neurophysiol., 2000).

During auditory training, in animals discriminating the auditory stimuli, patterns in auditory cortex developed with learning in accordance with our previous results. In addition, patterns could also be observed in the visual cortex in later training sessions, and at later post-stimulus time points within a trial. During visual training, in animals not showing correct responses during the first training sessions, we suspect that there was no transfer learning. Also, in these animals no significant patterns could be detected in the early training sessions. Nevertheless, some animals started to develop correct responses in later phases of the training. For these animals patterns could be identified in the visual cortex. For animals showing correct discrimination already during the first visual training sessions we suspect that they transferred the rate-response association learned during auditory training to the visual training. In these animals patterns could be detected in both the auditory and the visual cortex already during the first training sessions. We suggest that in these animals activity in both auditory and visual cortex was instrumental for achieving the crossmodal transfer of learned associations.

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DAY 2 - TUESDAY

Saccade characteristics reveal the timing of somatosensory encoding

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Background
When you haptically explore an object it is necessary to integrate information about the location of somatosensory input on the skin (touch) with information about the posture of the stimulated limb (proprioception). To investigate the time course of the integration between touch and proprioception, we analysed eye movements directed to somatosensory targets. That eye movements can be very informative about tactile encoding has been shown, among others, by Groh and Sparks (1996), who found that saccade trajectories to somatosensory targets on the hands are curved when the hands are crossed over the body midline. At the onset of the saccade only the somatotopic (skin) location is available and thus the saccade will be initiated towards that side of the body. When the somatotopic location is translated into an external frame of reference by integrating proprioception, the saccade direction is adjusted and the resulting saccade is curved. Thus, the curvature of saccades can inform us on the timing of integration of touch and proprioception.

Method
We measured eye movements to somatosensory targets on the hands in a crossed or uncrossed arm posture. In order to control the time of the onset of the saccade, we used a delayed response procedure in half of the trials. Thus, four blocks of trials were measured: crossed, no delay; crossed, delay; uncrossed, no delay; uncrossed, delay. The participants were seated with their arms either crossed or uncrossed and their ring fingers placed at marked locations just below the outer sides of a computer screen. Solenoid tappers were taped to the dorsal side of the distal phalanx of both ring fingers. The participant's head position was fixed by a chinrest, and a head-mounted Eyelink II® eye tracker recorded their eye movements. The arms and hands could not be seen by the participant. A trial started by the participant fixating a cross in the middle of the screen, followed by a stimulation of one of his ring fingers. The task for the participant was to make a saccade to the felt location of the stimulus as quickly and accurately as possible, after the go signal.

Results & Discussion
We analysed error rates, saccade trajectories, and saccade latencies. More errors were made when the hands were crossed, indicating the difficulty of the task while assuming this posture. We did not find any differences in the any of the properties of the saccades between the delayed crossed and uncrossed conditions and the no-delay uncrossed condition. Mean saccade onset latency was longer when the hands were crossed as compared to when they were uncrossed in the non delayed conditions. Participants made some curved saccades in the no-delay crossed condition, but they were less frequent than what was found by Groh and Sparks (1996). Yet, the few curved saccades that were found were made when the saccade latency was relatively short. This pattern may indicate that in the crossed-hands condition participants wait for the somatosensory input to be integrated with proprioception, before executing the saccade. This strategy (possibly learned) could help them to avoid errors in the execution of saccades in the crossed hand condition, but not in the uncrossed condition. Thus, the difference in saccade latency between crossed and uncrossed arm configurations is an indication of the timing of integration of somatosensory input with proprioception.

Reference
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Auditory-Visual Interactions and Rhythmic Structure

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Many meaningful auditory stimuli in the natural world have a rhythmic structure, for example the beats in music and stress patterns in speech. Even infants are able to detect these auditory patterns and it is thought that rhythmic regularities of stress and prosody in speech play an important role in infants' early language acquisition. We are interested in whether rhythmic structure may have a broadly organizing role across modalities, and what the hallmarks of such organization are at the behavioural level. In this task, adult participants were asked to detect a brief visual flash that was presented either within a strong auditory rhythmic context, or without a rhythmic context. Rhythmic auditory beats were presented at a rate of 1.67 Hz (600 ms period) and visual flashes were presented in alternate auditory periods with ISIs varying randomly between 20 ms and 500 ms in 20 ms steps. In a unimodal baseline task, visual flashes were presented with the same temporal distribution, but in the absence of any background auditory rhythm. Participants' reaction times to the flash for each of the 25 ISI values were plotted to create a reaction time profile across the whole auditory period. The pattern of this profile was compared in bimodal and unimodal conditions.

We report two major findings. Firstly, facilitatory effects in the bimodal condition were observed, but these were only significant toward the end of the auditory period. That is, compared to the visual-only baseline, there was no net facilitatory effect observed when the flash immediately followed the sound. Reaction times to the flash were only significantly faster at longer lags when the next sound was imminent, which may suggest the presence of anticipatory effects based on estimation of the auditory rhythmic interval. Secondly, there were differences in the reaction time profile pattern of the two conditions. Both conditions were characterized by a decreasing trend in reaction time across the auditory period. However, we also observed small but regular periodic patterns of fluctuation in reaction time throughout the auditory period. These regular patterns were present in the bimodal condition but not in the unimodal condition. Since neural oscillatory activity has been shown to correlate with behavioural reaction times both in animal (Lakatos et al, 2008) and human studies (Senkowski et al, 2006), it would be interesting to test whether the temporal pattern of effects observed here are related to neuronal oscillatory activity.

In summary, our results indicate that auditory facilitation of visual detection shows a temporal dependency on rhythmic period, and the pattern of this temporal dependency shows evidence of more complex organization. Secondly, our data suggest that temporal rhythm may have a wide-ranging influence across sensory systems. That is, temporal regularity in the auditory modality may structure motor responses to irregular input arriving through the visual modality.

DAY 2 - TUESDAY

A Comparison of Audio-Visual Interactions in Magno - and Parvocellular Visual Pathways

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One of the most fundamental dissociations within the visual system (functional and anatomical) involves the distinction between the magnocellular (M-) and parvocellular (P-) visual pathways subserving the ventral and dorsal cortical processing streams, respectively. Activity in the M-pathway is related to object detection, motion and depth perception, and primarily supports automatic goal-directed actions, such as orienting movements. The P-pathway processes stimulus information related to form and colour and is primarily involved in object perception, recognition and identification.

Audio-visual sensory integration can modulate perceptual performance on visual tasks, but these multisensory interactions have not been assessed in the context of the M- and P- visual pathways separately. In the present study we employ a psychophysical paradigm called the 'Steady vs. Pulsed Pedestal' method, which is known to reveal the spatial contrast signatures of each pathway. The results compare spatial contrast thresholds in the presence or absence of auditory stimulation, in order to determine if additional multisensory stimulation enhances performance differentially in each pathway. We discuss the results in the context of action and perception.

Perception of emotion in face and voice: Crosscultural comparison

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Purpose
Previous studies have shown that when there is an incongruency between the emotions expressed in face and voice, perception of the emotion in one modality is biased by the other modality. This crossmodal bias effect is presumably automatic as it occurs even under instructions to base the judgement exclusively on one modalitiy. The present study investigates how cultural experience modulates emotional processing of face and voice.

Methods
Participants were native speakers of Japanese (N = 24), Dutch (N = 20), and English (N = 17). Dynamic face and voice were recorded from the native speakers of Japanese and Dutch. In the experiment, face (happy or anger) and voice (happy or anger) were presented simultaneously (i.e. the emotions of the face and the voice were congruent or incongruent). In the face task, participants categorized the emotion of the faces into happy or anger. In the voice task, participants categorized the emotion of the voices.

Results
In the voice task (Figure 1), we obtained a large congruency effect, suggesting that emotional valence of voice is "affectively ventriloquized" by that of dynamic emotional images. Main effect of Group was also significant, showing that Japanese people are better at recognizing the emotion by voice. Vocal emotion of Japanese speakers was better recognized by Japanese participants (Figure 1a) whereas that of Dutch speakers was better recognized by Dutch groups (Figure 1b). In the face task (Figure 2), the performances were almost perfect in all of the conditions. However, there was a small but significant cogruency effect only in Japanese group.

Conclusions

Japanese people are sensitive to the emotion of the voice regardless of whether they pay attention to face or voice. Vocal emotion of native speakers was better recognized by both Japanese and Dutch groups. Emotional valence of voice is "affectively ventriloquized" by dynamic emotional faces.

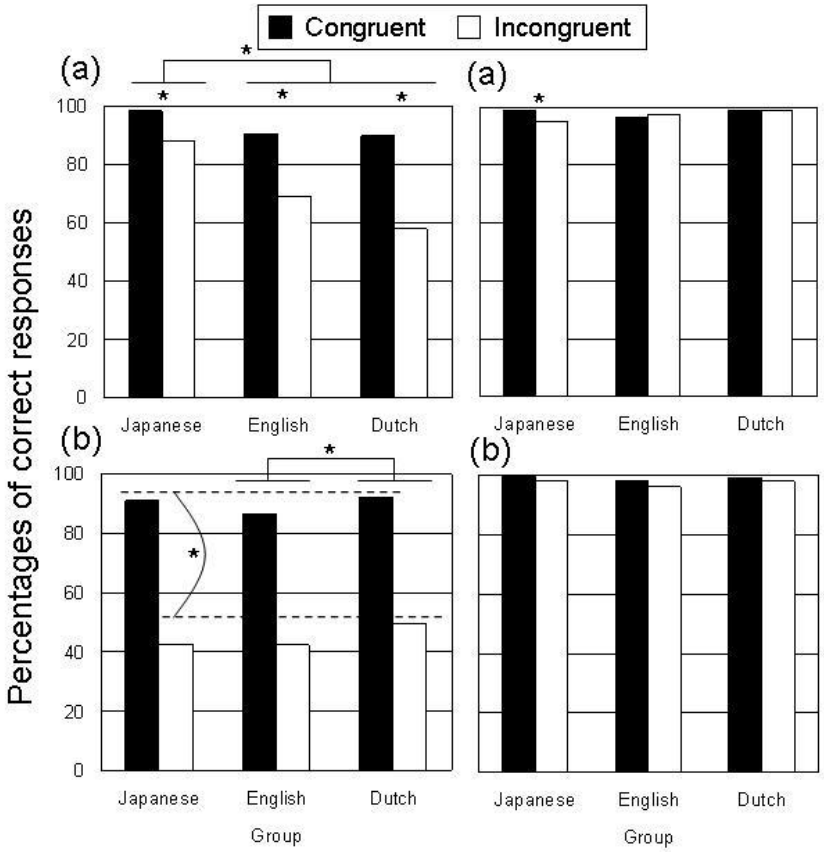

Figure 1: Performances in the voice task. (a) Japanese speaker stimuli and (b) Dutch speaker stimuli.

Figure 2: Performances in the face task. (a) Japanese speaker stimuli and (b) Dutch speaker stimuli.

Effect before cause: sensorimotor temporal recalibration across the senses

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Our motor actions normally generate sensory events, but how do we know which events were self generated and which have external causes? Here we show that adaptation to artificially-induced delays between action and event can produce a startling percept - upon removal of the delay it feels as if the sensory event precedes the action which was intended to cause it (Stetson et al. 2006). This temporal recalibration of action and event occurs in a quantitatively similar manner across the sensory modalities. Critically, it is robust to the replacement of one sense during the adaptation phase with another sense during the test judgment. This suggests a high-level, supramodal recalibration mechanism. The effects are well described by a simple Bayesian model which incorporates a prior expectation of synchrony between action and event – an expectation which is challenged during adaptation to induced sensorimotor delays. We further demonstrate that our model may have relevance for temporal adaptation data outside the sensorimotor domain. Recent findings from (purely sensory) audiovisual adaptation experiments (Fujisaki et al. 2004) are well described by the a modified version of the model where signals are recalibrated by an assumption of synchrony that is weaker than it's sensorimotor counterpart but tuned over a similar temporal range.

Neural correlates of audiovisual speech integration in second language

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Introduction: Speech is inherently audio-visual (AV). It is well established that gain in performance afforded by AV speech is greater the smaller performance is in the unimodal conditions (inverse effectiveness). Coherently, it has been suggested that behaviourally AV speech is of even greater importance to non-native speakers (Wang 2008). Candidate multisensory integration (MSI) sites underpinning AV speech perception have been proposed, but little is known about speech-related MSI sites during non-native language perception. Previous results highlight showed that the left superior temporal gyrus (STG) plays a critical role in integrating AV speech and that the congruency (i.e. the temporal relationship) between the sensory modalities modulates activation in this area (Calvert 2001).

Aims: We hypothesized that the effects of AV congruency during speech comprehension in non-native language (L2) would involve the STG differentially as compared to native the language (L1).

Methods: Twenty-one healthy native speakers of Spanish (L1) who had learned English (L2) before adulthood participated in this fMRI study. Mean age of acquisition of the L2 was 11 years. Participants were scanned in two separated runs, one in each of two languages (English or Spanish). Five conditions were presented during each run in a blocked design: auditory alone (A-), visual alone (-V), congruent audiovisual (AVc), incongruent audiovisual (AVi) and a rest condition (blank screen). Runs and conditions were counterbalanced across subjects. Thus, participants could listen (A-), see (-V) or simultaneously hear and see (AVc and AVi) a male Spanish/English bilingual speaker at each respective condition. FMRI data sets were acquired applying a sparse sequence (TR=8-s. TA= 2-s.).

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Results: The post-scanning recognition test returned above chance performance for AVi, AVc and A stimuli. The imaging results showed that the posterior portion of the STG was bilaterally more active in the AVc condition than in the AVi condition when presented with L2 stimuli, but not L1. The opposite contrast did not reveal any significant activation. Audio-visual congruency effects between languages showed the involvement of the left posterior STG when presented with L2 more than L1. On the other hand, L1 showed a higher activation than L2 in the anterior portion of the STG. Left posterior STG showed an interaction effect across languages and congruency conditions. Thus, its activation was higher during AVc than AVi for L2, and just the opposite for L1.
Conclusions: In accord with Calvert (2001), we confirm that AV speech congruency modulates activity in the posterior STG. We expand this result showing that this same effect is larger for L2 than for L1. We speculate that the left STG may play a key role in integrating AV speech under a impoverished informational conditions (e.g during L2 comprehension) and that this same area is less responsive in a less demanding task when the visual channel benefit is of lesser importance.

DAY 2 - TUESDAY

Examining cross-modal influence of the auditory brainstem response

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While sensory systems have classically been defined and studied in isolation of one another, interactions have been shown at both the cortical and sub-cortical levels, with some studies showing visual influence even in brainstem level auditory structures (Musacchia, Sams et al. 2006). Recent evidence for enhanced auditory brainstem response when paired with concurrent visual stimulation is particularly intriguing, especially considering other work suggesting attention-related mediation of the frequency-following response (FFR) component (Galbraith, Olfman et al. 2003). Here, we extend this work to explore the possibility of attention-mediated suppression of the brainstem FFR, analogous to what has been shown cortically ("cross-modal deactivation", e.g. (Hairston, Hodges et al. 2008). Additionally, we seek to further explore the connection between brainstem- and cortical-level attenuation within the same paradigm.

Subjects (currently recruiting) perform fairly difficult visual and auditory duration-discrimination tasks within separate blocks. Stimuli are adjusted according to each subject's perceptual threshold, acquired during prior testing to ensure equivalent difficulty and sufficient attention to the target modality. Background non-task relevant tones (220Hz) are used to elicit the brainstem 220Hz FFR, with occasional oddball stimuli (259Hz) providing a cortical mismatch-negativity response. Fourier power for the principle background (220Hz) frequency is compared for each modality above resting (no-task baseline). We anticipate not only enhanced power during auditory tasks, but an attenuated signal when attention in focused on vision, suggesting that cross-modal inhibition can affect processing almost immediately after reception.

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DAY 2 - TUESDAY

Auditory-visual multisensory interactions between task-irrelevant stimuli engage distinct configurations of brain networks at early latencies in humans

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Event-related potential (ERP) investigations of auditory-visual (AV) interactions in humans have documented non-linear effects beginning ~50ms post-stimulus onset in response to rudimentary stimuli and during discrimination (Giard and Perronet, 1999 J Cogn Neurosci) or detection tasks (Molholm et al., 2002 Brain Res Cogn Brain Res). These findings and more generally the use of an additive model to test for multisensory effects with ERPs have been criticized, in part due to so-called 'common' activity related to task performance (Teder-Salejarvi et al., 2002 Brain Res Cogn Brain Res; Gondan et al., 2005 Percept Psychophys). An independent shortcoming of these prior works is that no analyses were performed that would discern whether non-linearities stemmed from modulations in response strength and/or response topography; the latter of which would indicate the recruitment of distinct configurations of brain generators during multisensory processing. Moreover, in one of these studies were source estimations performed, limiting the information these studies could provide on the likely underlying generators. Here, we performed electrical neuroimaging analyses of ERPs from 12 subjects in response to task-irrelevant auditory, visual, and AV multisensory stimuli. Importantly, because subjects were performing a motion detection task, attention was maintained on both sensory modalities (detailed in Cappe et al., 2009 Neuropsychologia), circumventing the criticisms of uncontrolled attention and the absence of a need to integrate multisensory information associated with passive paradigms (though see Vidal et al. 2008 Clin Neurophys for evidence of early non-linear effects during passive conditions). On the one hand, we replicate previous findings by showing there to be non-linear neural response interactions of individual ERP waveforms starting at ~55ms. Thus, comparably timed AV interactions can be reliably obtained when stimuli are task-irrelevant, but still attended. We then extend these findings to show that this initial non-linearity is the consequence of topographic modulations and not simply the result of pure amplitude enhancement. These effects indicate that multisensory interactions engage distinct configurations of brain networks, rather than simply modulating the strength of unisensory activity. Finally, we performed source estimations to identify the likely regions mediating these effects. We discuss our results both in terms of methodological/analytical considerations for multisensory research using ERPs and in terms of extant models of AV multisensory interactions.

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Different Neural Frequency Bands Integrate Faces and Voices Differently in the Superior Temporal Sulcus

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Effective functioning in natural environments demands the integration of input from different modalities such as vision, audition, and touch. For example, in face-to-face communication, combining visual and auditory information leads to better discrimination of speech. Naturally, the neural systems underlying such audiovisual integration have received considerable attention. As functional magnetic resonance imaging and electrophysiological studies reveal, the regions in and around the superior temporal sulcus (STS) are implicated in this process. In humans, MEG or EEG studies show a suppression of the evoked audiovisual response relative to the evoked auditory response in electrodes over the superior temporal sulcus / gyrus (STS / STG). Finally, studies have also implicated different frequency bands such as alpha, beta, and gamma in the processing of audiovisual stimuli [1]. It is unclear how these disparate metrics relate to each other in the processing of audiovisual stimuli.

To relate these findings and provide greater insights into the network-level dynamics of the STS during audiovisual integration, we used a macaque model system to analyze the different frequency bands of local field potential (LFP) responses to the auditory and visual components of vocalizations. These vocalizations (like human speech) have a natural time delay between the onset of visible mouth movements and the onset of the voice (the "time-to-voice" or TTV). We show that the LFP responses to faces and voices elicit distinct bands of activity in the theta (4–8 Hz), alpha (8–14 Hz), and gamma (>40 Hz) frequency ranges. Along with single neuron responses, the gamma band activity was greater for face stimuli than voice stimuli. Surprisingly, the opposite was true for the low-frequency bands—auditory responses were of a greater magnitude. Furthermore, gamma band responses in STS were sustained for dynamic faces but not so for voices (the opposite is true for auditory cortex). These data suggest that visual and auditory stimuli are processed in fundamentally different ways in the STS. Finally, we show that the three bands integrate faces and voices differently: theta band activity showed weak multisensory behavior regardless of TTV, the alpha band activity was enhanced for calls with short TTVs but showed little integration for longer TTVs, and finally, the gamma band activity was consistently enhanced for all TTVs. These data demonstrate that LFP activity from the STS can be segregated into distinct frequency bands, which integrate audiovisual communication signals in an independent manner and perhaps reflect the different scales of the network involved in audiovisual integration. Our analysis of field potential responses in the STS [2] along with prior results from our group from auditory cortex [3, 4] provide a better understanding of the dynamics of audiovisual integration in the regions in and around the superior temporal sulcus / gyrus.

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DAY 2 - TUESDAY

Audio-visual integration of emotional processing: Evidence from event-related potentials

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Three experiments were run to analyze audio-visual integration in emotional processing. In the first experiment, participants were instructed to categorize the emotion and rate the intensity of happy, sad, angry and neutral dynamic facial and vocal expressions while they had to attend either to the face or the voice. Emotional expressions were presented as a voice, as a face (unimodal) or as a combination of emotionally congruent (bimodal congruent) or emotionally incongruent (bimodal incongruent) face-voice pairs. Participants showed lower performance in the bimodal emotionally incongruent condition compared to the unimodal or bimodal emotionally congruent condition. This incongruency effect could be due to a response conflict and/or to an emotional conflict. To control this confound, the second experiment consisted of a modified version of experiment 1: Emotional conflict and response conflict were separated. Behavioral data showed shorter reaction times to bimodal emotionally congruent compared to bimodal emotionally incongruent trials even without response conflict. In a third experiment, the time course of audio-visual emotional integration was analyzed using event-related potentials (ERPs). Results suggest early incongruency effects: A more pronounced positivity for bimodal emotionally congruent trials compared to bimodal emotionally incongruent trials at 190-230 ms for both the attended and unattended modality with a fronto-central scalp distribution was found. This effect is not due to a lack of attentional processing since unimodal vocal and facial attention effects were observed at the same time window (190-230 ms). In sum, these results suggest uni- and crossmodal attention effects in audio-visual integration of emotions.

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Facilitation and Interference Effects in Crossmodal Semantic Priming

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Crossmodal semantic priming paradigms compare responses to target stimuli in one sensory modality following presentation of semantically congruent or incongruent primes in another modality. Using one such paradigm with natural object stimulus pairs, congruent primes in both visual and haptic modalities have recently been shown to improve responses to auditory targets when compared with incongruent primes (Schneider et al., 2008, Experimental Psychology; IMRF 2008). Here we extended this investigation by comparing the effects of congruent and incongruent auditory primes on responses to visual targets. Moreover, in order to ascertain whether crossmodal congruency effects result from interference (in the case of incongruent primes) or from facilitation (with congruent primes), or both, we also compared responses in each case to a neutral control condition where visual targets were preceded by a meaningless visual prime. Eighteen healthy adult volunteers were asked to classify natural objects shown in degraded pictures as either large or small. Presentation of pictures was preceded by a short congruent or incongruent sound or by a small grey square. During the task, EEG was recorded from 68 electrodes. One-way repeated-measures ANOVAs showed significant differences between the three conditions ($p<.01$) in terms of both accuracy and response time (RT). Pairwise comparisons confirmed better performance both in accuracy and RT in the congruent condition compared with incongruent ($p<.05$). When compared with the control condition, performance was less accurate in the incongruent condition ($p<.05$), whereas RT was faster in the congruent condition ($p<.05$). No other pairwise comparisons were significant. This pattern of results suggests that both facilitation and interference processes contribute to crossmodal semantic priming. EEG data will be presented exploring the neurophysiological mechanisms of these effects.

Evidence for distinct roles of posterior superior temporal sulcus and inferior frontal areas in audiovisual action recognition

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Liverpool University

Introduction: We previously reported significant interactions in BOLD response for congruent and incongruent semantic audiovisual action sequences (whole-body actions and speech actions) in bilateral pSTS (BA 22), left SMA (BA6), left IFG (BA44) and IPL (BA 40). We found strong activation but no interaction in bilateral premotor areas (BA 6) or in conditions where meaningful actions were paired with meaningless stimuli.

Here we present the results from a high density EEG study that complement the fMRI data and suggests distinct roles for pSTS and left IFG in the integration of bimodal action sequences.

Methods: 11 subjects (7 female, age range 20-43 yrs, all right handed) were presented with audio-visual displays of whole-body actions and speech syllables. The stimuli could be congruent or incongruent (body motion in one modality, speech in the other). Subjects were asked to respond to stimulus repetition in one or both modalities (10% of stimuli). EEG data was recorded with a 129 channel dense sensor net (Electrical Geodesics Inc, Eugene OR, USA). Ocular artefact removal and statistical channel and epoch selection (SCADS, Junghöfer et al., Psychophysiol, 2000) was used to obtain artefact free epochs. The pooled ERPs for the two conditions were compared to identify areas and times of significant difference. Dipoles were fitted (BESA, MEGIS Software GmbH, Munich) to associate the time windows of interference with activity in source locations. RESULTS: Responses to congruent stimuli are larger between 250ms and 350ms after stimulus onset in left frontotemporal electrodes. The response to incongruent stimuli is larger in left inferior frontal electrode positions from 600ms after stimulus onset. The difference around 300ms can be explained by a modulation of sources in the superior temporal area while the response difference after 600ms is consistent with an increase of activity in the left IFG.

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Conclusions: Our results are consistent with a model that postulates early recognition of congruent audiovisual actions in the pSTS, perhaps as a sensory memory buffer, and a role of the IFG, perhaps in a generative capacity, in reconciling incongruent signals.

DAY 2 - TUESDAY

From unsupervised to supervised categorization in vision and haptics

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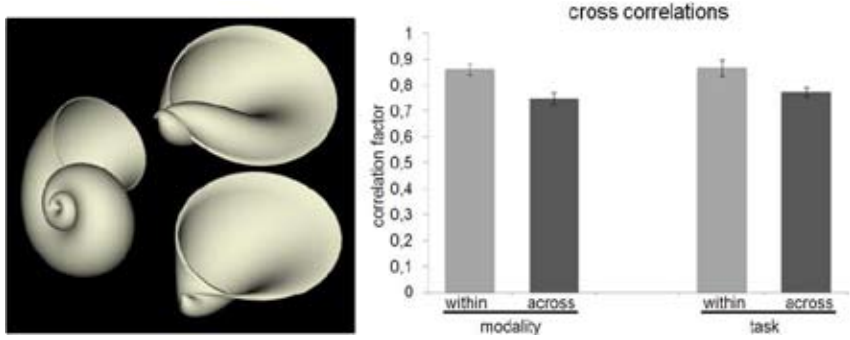
Max Planck Institute for Biological Cybernetics

Categorization studies have primarily focused on the visual percept of objects. But in every-day life humans combine percepts from different modalities. To better understand this cue combination and to learn more about the mechanisms underlying categorization, we performed different categorization tasks visually and haptically and compared the two modalities. All experiments used the same set of complex, parametrically-defined, shell-like objects based on three shape parameters (see figure and [Gaissert, N., C. Wallraven and H. H. Bülthoff: Analyzing perceptual representations of complex, parametrically-defined shapes using MDS. Eurohaptics 2008, 265-274]). For the visual task, we used printed pictures of the objects, whereas for the haptic experiments, 3D plastic models were generated using a 3D printer and explored by blindfolded participants using both hands.

Three different categorization tasks were performed in which all objects were presented to participants simultaneously. In an unsupervised task participants had to categorize the objects in as many groups as they liked to. In a semi-supervised task participants had to form exactly three groups. In a supervised task participants received three prototype objects (see figure) and had to sort all other objects into three categories defined by the prototypes. The categorization was repeated until the same groups were formed twice in a row. The amount of repetitions needed across modalities was the same, showing that the task was equally hard visually and haptically. For more detailed analyses we generated similarity matrices based on which stimulus was paired with which other stimulus. As a measure of consistency – within and across modalities as well as within and across tasks – we calculated cross correlations between these matrices (see figure). Correlations within modalities were always higher than across modalities. In addition, as expected, the more constrained the task, the more consistently participants grouped the stimuli. Critically, multi-dimensional scaling analysis of the similarity matrices showed that all three shape parameters were perceived visually and haptically in all categorization tasks, but that the weighting of the parameters was dependent on the modality. In line with our previous results, this demonstrates the remarkable robustness of visual and haptic processing of complex shapes.



DAY 2 - TUESDAY

Veridical auditory information enhances visual sensitivity to biological motion

James Philip Thomas, Maggie Shiffrar

Rutgers University

People exhibit remarkable sensitivity to point-light displays of human movement. The Superior Temporal Sulcus is strongly implicated in the visual perception of human action. Additionally, STS has been implicated in the integration of signals across modalities, potentially resulting in the formation of multimodal action representations. On these bases, we hypothesized that the addition of auditory cues corresponding to actions depicted in point-light displays would improve visual sensitivity to those actions.

To test this hypothesis, a psychophysical study was conducted wherein participants detected the presence of masked point-light walkers under unmoral or audiovisual conditions. Participants in audiovisual conditions heard either tones or actual footfalls coincident with the walkers' footsteps. Results revealed improvement in detection sensitivity when visual displays were paired with veridical auditory cues (footfalls), but not when paired with simple tones, suggesting that coincident cues are not sufficient to improve visual sensitivity to actions with which they do not naturally co-occur.

To investigate the role of temporal coincidence in the sensitivity benefit conferred for coincident/veridical footstep pairings, a second study was conducted wherein participants heard tones or footfalls that were either coincident with the walkers' footsteps or heard at random times within each trial. Two-way ANOVA revealed a main effect of sound, but no main effect of timing and no interaction. Observed increases in visual sensitivity were driven by the semantic relationship, and not by the temporal correspondence, between modality-specific cues. Under some conditions, integration of multimodal cues to human action may occur irrespective of temporal asynchronicity.

Gender and Vision in the Crossed Hands TOJ Deficit

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Participants judged which of two vibrotactile stimuli presented to the index fingers or thumbs occurred first. Past research has shown performance on this vibrotactile temporal order judgment (TOJ) task was more accurate when the hands were kept in their respective hemispaces, compared to when the hands were crossed over the midline. We examined the role of vision in this crossed-hands TOJ deficit by implementing three different visual conditions: eyes open with the lights on, eyes open with the lights off, and eyes closed with the lights off. No differences were seen. However, upon closer examination of the data, a significant effect of gender was found, such that male participants showed a smaller crossed-hands deficit than female participants. This overall difference was seen in the context of large individual differences.

Fronto-parietal areas necessary for a multisensory representation of the Peripersonal Space in humans: a r-TMS study

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University of Bologna

In monkeys, bimodal neurons in premotor and parietal areas are thought to underlie a multisensory representation of the space around the body, i.e. peripersonal space (PPS; Graziano & Cooke, Neuropsychologia, 2006). In humans, neuroimaging data show that neural activity in the ventral premotor (VPM) and in the posterior parietal (PPC) cortex is modulated by poli-sensory stimuli approaching the body (see Makin et al., Behav Brain Res, 2008). In the present study, we directly tested in humans whether VPM and PCC have a necessary role in a multisensory representation of the PPS.

We used low frequency r-TMS to induce a transient virtual lesion of these two areas and of V1, serving as a control site, and tested whether this experimental manipulation affected audio-tactile integration in the space around the hand. Subjects performed a speed response task to a tactile stimulus on their right (controlateral to TMS stimulation) hand while concurrent task-irrelevant sounds were presented either near the hand (at 5 cm) or in the far space (at 100 cm).

In a Baseline condition, when no TMS stimulation was delivered, reaction time to tactile targets was speeded up if a sound was presented near the hand rather than in the far space, thus showing multisensory integration within the boundaries of the PPS. The speeding effect associated to near sounds disappeared when the same task was performed after inhibitory TMS over VPM and over PPC, thus suggesting a disruption of the multisensory integrative mechanism around the hand. Such result was not a generic consequence of TMS, because when the stimulation was administered over the control site V1, the response to tactile targets was faster when near rather than far sounds were presented.

These findings show that audio-tactile integration around the hand depends on the function of both the ventral premotor cortex and of the posterior parietal cortex.

Audiovisual synchrony detection for speech and music signals

Hwee-Ling Lee, Uta Noppeney

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Introduction: Audiovisual integration crucially depends on the relative timing of the auditory and visual signals. Although multisensory signals do not have to be precisely physically synchronous in order to be perceived as single temporal events, they have to co-occur within a certain temporal window of integration. To investigate how the human brain is fine tuned to the natural temporal statistics of audiovisual signals, we characterized the temporal integration window for natural speech, sinewave replicas of natural speech (SWS) and music in a simultaneity judgment task.
Methods: The experimental paradigm manipulated: 1) stimulus class: speech vs. SWS vs. music, and 2) stimulus length: short (i.e. natural syllables, SWS syllables and tones) vs. long (i.e. natural sentences, SWS sentences and melodies). Audiovisual asynchronies ranged from -360ms (auditory leading) to 360 ms (visual leading) in 60ms increments. Eight participants performed the experiment on 2 separate days. The order of conditions was counterbalanced within and between subjects. The proportion of synchronous responses was computed for each participant. To refrain from making any distributional assumptions, the psychometric curves of each participant were characterized by four indices: (i) peak performance, (ii) peak location, (iii) width and (iv) asymmetry [1]. The four indices were analyzed using repeated measures of ANOVAs with stimulus class and stimulus length as within-subjects factors.
Results: The ANOVA for peak performance did not show any significant main effects of stimulus class and length [$F(2,14)<1$, n.s.; $F(1,7)=1.6$, $p=.24$]. The ANOVA for peak location revealed a significant interaction between stimulus class and length [$F(2,14)=3.8$, $p<.05$]. Post-hoc paired t-tests revealed that the peak locations were significantly shifted towards auditory leading for melodies compared to tones [$t(7)=2.4$, $p<.05$], and for melodies compared to SWS sentences [$t(7)=-2.3$, $p=.053$]. The ANOVA for width revealed significant main effects of stimulus class and length [$F(2,14)=9.3$, $p<.005$; $F(1,7)=11.0$, $p<.05$] in the absence of an interaction [$F(2,14)<1$, n.s.]. Post-hoc paired t-tests revealed that the widths were wider for SWS speech than

natural speech [t(7)=7.0, p<.005] and music [t(7)=2.4, p=.05]. Furthermore, the widths were narrower for long stimuli (i.e. sentences and melodies) than short stimuli (i.e. syllables and tones) [t(7)=-3.3, p<.05]. With respect to the asymmetry, there was a significant main effect of stimulus length [F(1,7)=7.1, p<.05] but not stimulus class [F(2,14)=1.1, p=.35], thus indicating that the psychometric curves were more asymmetric for long stimuli (i.e. sentences and melodies) than short stimuli (i.e. syllables and tones).
Conclusion: Our results demonstrated that the psychometric curves were narrower and more asymmetric for long stimuli (i.e. sentences and melodies) than short stimuli (i.e. syllables and tones). Thus, participants may rely on information during the entire sentence for synchrony judgments. In addition, our results demonstrated that the psychometric curves were wider but less asymmetric for SWS speech relative to natural speech and music. Collectively, our results support the hypothesis that audiovisual speech perception is fine-tuned to the natural mapping between facial movement and spectrotemporal structure of natural speech.

Reference:

1. Maier J., Luca M.D. and Noppeney U. (2009). Audiovisual asynchrony detection in human speech (submitted).

Granger causality mapping reveals congruency-dependent directed influences from superior temporal to auditory cortex during audiovisual integration

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Objective

How do sensory-specific and multisensory brain regions interact during multisensory integration? Previous neuroimaging studies provide contradictory evidence, especially with regard to the role of multisensory regions such as the superior temporal sulcus (STS). Here, we directly examined the role of STS in the audiovisual integration of letters and speech sounds by mapping directed interactions to and from STS over the brain. Based on previous results [1,2] we predicted that directed influence from STS to auditory cortex is stronger for congruent than for incongruent letter-sound pairs.

Methods

10 subjects passively perceived randomly presented letters, speech sounds, and congruent or incongruent letter-sound pairs. Scanning (3T) repetition time was 2s and volume acquisition time 1.5s; stimuli were presented in the silent 500ms delay. Random-effects general linear models (GLMs) were used to create statistical maps of the congruency contrast [congruent vs. incongruent]. Effective connectivity was assessed using Granger Causality Mapping (GCM) [3], which identifies voxels that are sources/targets of directed influences to/from a selected reference region-of-interest (ROI). We selected ROIs in STS in 10 individual subjects using the conjunction of [Auditory > baseline] □ [Visual > baseline], which indentifies heteromodally responsive voxels. Using this left STS ROI as reference region, single-subject Granger causality maps (GCMs) were calculated for the congruent and incongruent conditions. Next, a random-effects group GCM was created to test modulation of effective connectivity by congruency (modulation map).

Results
The GCM modulation map demonstrates an influence from the left STS to auditory cortex bilaterally and right occipital cortex that was stronger during congruent letter-sound pairs than incongruent pairs. The auditory cortex regions targeted by STS are the same as in which a congruency effect (congruent > incongruent) was observed using GLM analysis in the present as well as in previous studies [1,2].

Conclusions
The GCM results indicate that the STS provides congruency-dependent feedback to auditory and visual sensory-specific regions during audiovisual integration. This suggests that
multisensory STS can be a crucial component during integration of meaningful auditory and visual information. Mapping directed influences to and from the targeted low-level sensory regions is currently in progress, to further confirm and extend the present results.

[1] van Atteveldt et al., Neuron, 2004

[2] van Atteveldt et al., Cerebral Cortex, 2007

[3] Roebroeck et al., Neuroimage, 2005

Crossmodal corticocortical projections preferentially terminate in supragranular laminae

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Convergence is the defining step of the multisensory process. Identification of multisensory convergence often first occurs through physiological methods, but the issue of how multisensory properties arise is based on connectivity. Over the years, numerous anatomical studies have been conducted that identify the areal sources of convergent input to established multisensory regions, yet few have assessed the patterns of terminations generated by those inputs. Toward that end, we examined the termination pattern of crossmodal inputs to areas of cat cortex: visual PLLS, somatosensory SIV and RSS, and auditory FAES. Tracer injections (BDA) into afferent sources of these regions consistently revealed orthograde projections that preferentially terminated in the supragranular layers of the target regions. Only the fundic portion of the RSS appeared to deviate from this pattern. This supragranular preference was observed for projections from association, as well as core and belt cortices. Given that the designations of feedback/feedforward are based on studies of intramodal connections, these data suggest that crossmodal projections may follow another set of rules to be identified by further study of the issue of projection termination preferences.

Spatial integration of audio-visual infromation in the peripheral visual field

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Tohooku Univ

Audio-visual integration has been investigated by many researchers, primarily limited to the central visual field. However, humans have a peripheral visual field in addition to the central visual field. In auditory perception, humans can localize sound sources within the full three-dimensional space. As such, we have conducted a study on audio-visual integration which extends from the central visual field to include the peripheral visual field. The experimental task was for participants to judge the spatial coherence of auditory and visual stimuli presented simultaneously. The experiment was conducted in a dark anechoic room. The visual stimulus consisted 7 white light-emitting diodes (LED's) positioned at 7 different angles (-70°, -40°, -20°, 0°, 20°, 40°, 70°) relative to the fixed head position. The auditory stimuli were presented using an array of 37 small loudspeakers on an arc from -90° to 90° with 5° spacing. For any given test, the auditory range centered around the visual stimulus location. Judgments were made using an integer scale from 1 to 5. The lower end of the scale (1) indicated 'coincidence' of the presented auditory and visual stimulus, with the upper end of the scale (5) indicated that the spatial disparity between auditory and visual stimulus was the largest. Participants consisted of 9 males and 1 female. For visual stimulus presented at 0°, within the central visual field, results show left-right symmetry in spatial disparity between the auditory and visual stimuli, centered at 0°. Namely, the rating scale value increases symmetrically as the auditory stimulus moves further away from visual stimulus. In contrast, for visual stimulus within peripheral visual field, spatial left-right disparities between both stimuli were found to be asymmetrical. Not only was the perceived disparity on the farther side less accurate, the point of coincidence (lowest rating value) was shifted in the direction opposite from the 0° fixation point by 5°. These results suggest two types of distortion in the perception of audio-visual spatial integration in the peripheral visual field as compared to the central visual field.

The critical pre/post-event temporal range for stable crossmodal perception: Evidence from the stream/bounce display

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We investigated the temporal range that the perceptual system develops for crossmodal interaction. In particular, we focused on the synergy between the temporal ranges before and after the crossmodal (audiovisual) event, leading to stable crossmodal interaction. We utilized the stream/bounce display in which two objects with crossing trajectories are perceived as either streaming through or bouncing off each other. Although the streaming percept is dominant, a sound burst at the moment the objects coincide was reported to induce the robust bouncing percept. The presentation of the sound burst or none was manipulated at the coincidence point. Additionally, the presentation durations of the moving objects were varied before and after the coincidence point (pre/post-coincidence duration: 50, 100, 200, 300 ms). Observers were asked to judge whether the two objects appeared to stream through or bounce off each other. The results revealed that, when the pre-coincidence duration was over 200 ms, the sound-induced bouncing was fully obtained in the post-coincidence duration of approximately 100 ms. Meanwhile, in the pre-coincidence duration of less than 100 ms, it took the post-coincidence duration of about 200 ms to fully obtain the bouncing percept. Therefore, we suggest that crossmodal perception is developed by the synergy effect between pre- and post-event processing.

Multisensory integration in superior colliculus (SC) neurons: a computational study

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Neurons in the cat superior colliculus (SC) can integrate information from different sensory modalities and enhance their responses to cross-modal stimuli in spatiotemporal coincidence. These SC neurons receive unisensory inputs from many subcortical and cortical areas, but inputs from association cortex are critical. They are essential for the development of multisensory integration and for its expression during adulthood. The mechanisms underlying multisensory integration can be clarified with the use of mathematical models and computer simulations, and in recent years, we proposed a neural network model of the SC that can reproduce the different experimental results such as multisensory enhancement, and cross-modal and within-modal suppression. However, the model was unable to account for the maturation of multisensory integration or for its loss in adulthood during cortical deactivation. The objective of this work is to present an improved model which is able to explain these physiological features of multisensory integration and which incorporates recent neurological observations concerning the convergence patterns from cortical and subcortical sources and the impact of specific receptors. The model assumes the presence of competitive mechanisms between the inputs and nonlinearities in the NMDA receptor response. In a first stage of computer simulations, synaptic weights are arranged to mimic the behavior of an adult SC neuron, and the simulation produces results comparable to those from empirical physiological studies, including those with cortex deactivated and with NMDA receptor blockade. In a subsequent stage, development is simulated by assuming that association cortico-collicular synapses are present but not active, so that SC activity is dependent completely on other sensory inputs. Sensory experience is modelled by a "training phase" in which the network is repeatedly exposed to modality-specific and cross-modal stimuli at different locations in space. The synaptic weights of association cortico-collicular synapses are modified based on Hebbian rules. After the training period, SC neurons respond in an adult-like fashion to modality-specific and cross-modal stimuli. The model summarizes much of the present knowledge regarding cat SC and, using realistic synaptic learning rules, provides a theoretical framework for understanding how the development of multisensory integration is guided by early sensory experience.

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DAY 2 - TUESDAY

The impact of Multisensory and Unisensory Integration on covert and overt orienting

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The products of unisensory and multisensory integration within the Superior Colliculus were found to be appreciably different. Moreover, recent data from cats suggests that multiple stimuli from the same sensory modality only marginally enhance localization compared to cross-modal stimulus combinations. In the present study, we investigated whether the integration of stimuli from different modalities (cross-modal) and from the same modality (within-modal) have a different impact on spatial orienting in humans. To this aim, we asked subjects to perform a simple reaction time task (Experiment 1) and a localization task (Experiment 2), which comprised modality-specific stimuli (visual or auditory), cross-modal stimulus pairs (visual-auditory) and within-modal stimulus pairs (visual-visual). Although both the integrative modes shortened RTs compared to the best unimodal condition, the redundancy gain was significantly greater for cross-modal than within-modal stimulus combinations. Moreover, a violation of race model inequality was observed only for the cross-modal condition. In addition, cross-modal stimulus combinations yielded a greater improvement in stimulus localization, according to a Bayesian model of spatial integration. The present results suggest that the integration of stimuli from different modalities and from the same modality have a different impact on covert and overt orienting, and support the hypothesis that the behavioural products derived from multisensory integration are not attributable to simple target redundancy.

Behavioural investigations of audiotactile interactions in humans

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Despite the large number of functional similarities (e.g., Gescheider, 1970) as well as commonly shared neural substrates (e.g., Kayser, Petkov, Augath, & Logothetis, 2005), the interactions occurring between touch and hearing have so far been far less well explored than is the case for other sensory pairings. We present a series of studies aimed at investigating different aspects of the interactions between audition and touch. A speeded discrimination task was used to explore the possible occurrence of an audiotactile Colavita effect (Colavita, 1974). The simultaneous auditory and tactile signals showed a weaker competition than the one occurring in audiovisual and visuotactile pairings, thus providing evidence of an audiotactile sensory balance (Occelli, Hartcher O'Brien, Spence, & Zampini, 2009)
In another series of studies, we explored sensory correspondences, such as those occurring between the frequency of a sound and the relative elevation of a tactile stimulus. Using a modified version of the Implicit Association Task (Greenwald, McGhee, & Schwartz, 1998), better performance was observed in the compatible (vs. incompatible) blocks, thus providing empirical support for the crossmodal association between the frequency of a sound and the relative elevation of a tactile stimulus (Occelli, Zampini, & Spence, 2009a).
Sensory correspondences based on frequency have also been explored by testing whether people are able to match the frequency of stimuli presented within the same sensory modality (i.e., audition or touch) or crossmodally (i.e., one stimulus presented to the skin and the other to the ear). Both the flutter frequency range (i.e., frequencies <50 Hz) and the vibration frequency range (i.e., frequencies >50 Hz) were tested. The results showed that the matching of the stimuli when both are presented in audition is significantly more accurate than

the other two conditions. The accuracy in discriminating the tactile frequency differences is higher within the flutter (vs. vibration) range. Despite the difficulty in matching the auditory and tactile frequencies, performance was modulated by the magnitude of the discrepancy in the frequency pattern (standard vs. comparison stimuli) for stimuli presented in the flutter range. Thus, people can match frequencies presented crossmodally, provided that the frequencies are presented in the flutter (vs. vibration) range.

In the audiotactile motion domain, we have shown that the change of the physical properties of sound (i.e., the intensity and the typology) can differentially affect the audiotactile capture effect in a 'crossmodal dynamic capture task'. The capture effect of the 82 dB auditory distractors was significantly more pronounced than the one induced by the 75 dB auditory distractor, whereas performance in reporting the direction of the auditory motion was overall significantly better if the stimuli were presented at 82 dB vs. 75 dB (Occelli, Zampini, & Spence, 2009b). Moreover, while the crossmodal dynamic capture exerted by tactile distractors was comparable for either auditory stimuli consisting of white noise or pure tones, the capture effect induced by the white noise stimuli was significantly larger than that induced by the pure tones (Occelli, Spence, & Zampini, 2009c).

Another aspect of particular interest is the investigation of how the visual experience can modulate these audiotactile interactions.In one study, we compared the temporal perception between blind and sighted participants in a temporal order judgment (TOJ) task, with auditory and tactile stimuli presented from same vs. different positions. Our results (Occelli, Spence, & Zampini, 2008) showed that the redundant spatial information provided by non-visual information in frontal space exerted a selective influence on the performance of blind participants while the spatial arrangement of the stimuli did not modulate the performance of the sighted controls.

In summary, the results emerging from these studies highlight the multiplicity of ways in which auditory and tactile stimuli can interact, possibly suggesting further aspects to be investigated in future research.

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Unmasking the dichoptic mask by sound

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There is now burgeoning evidence for multisensory integration occurring at various levels of processing, but most studies concentrate on multisensory interactions using well-perceived stimuli. Here we examine whether multisensory interaction occurs with suprathreshold sound and invisible, dichoptically presented, visual stimuli, and whether sound helps the visual target to release from suppression. We used the continuous flash suppression paradigm in which a word presented to one eye was made completely invisible initially, due to strong suppression through binocular rivalry induced by dynamic-noise patterns shown to the other eye. Response latency of release from suppression by increased contrast of the word was measured and compared between different conditions. We found that a suprathreshold sound made the invisible word become more quickly visible in the dichoptic condition, but not when word and masks were superimposed and viewed binocularly. Upright words were detected faster than inverted ones only with dichoptic viewing but not with binocular viewing, and sound facilitated detection of the word only when they were spatially congruent. We suggest that sound helps to segregate two fused visual events (i.e., word and masks) and make the target more easily accessible to awareness.

DAY 2 - TUESDAY

Does Maximum Likelihood Integration Predict How we Perceive Walking Humans? A Study on the Audiovisual Integration of Biological Motion

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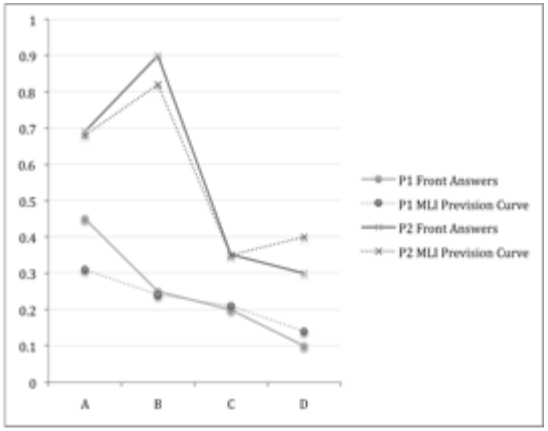
The MLI model has been shown to successfully predict multisensory integration processes given the reliability of each unimodal cue. But to what extent will it predict performance with behaviorally valid and semantically congruent stimuli is yet to be established. Here we test the theorem with familiar stimuli: walking humans and their step sounds. Biological motion perception is an inherently bimodal task, although there is barely no information on how we integrate both the visual and the auditory stimuli of this kind. These stimuli are potentially ambiguous and biased, as we tend to perceive them frontally, rather than backwards. It has been previously established that, given a highly ambiguous visual walker and easy to perceive human steps, the auditory clue becomes dominant (Mendonça & Santos, 2008). Here, we manipulated the amount of information conveyed by the auditory channel and analyzed how it interacted with the biased visual stimulus. We then confronted these results with the MLI prevision curves, based on the participant's results from the unimodal conditions.

We presented visually biased point-light-walkers, masked step sounds, or both simultaneously. Stimuli could be perceived as moving towards or away from the subjects. Participants were asked to point were the stimuli was oriented to. Results revealed that in spite of the large individual differences (see Figure 1), the MLI model accurately predicted their outcome in the audiovisual condition.

Our data supports the hypothesis that we perceive biological motion in an optimal fashion, as both the visual and the auditory stimuli are weighted differently according to one's interpretation and trust on each clue.

Figure 1: Results of two participants (P1 and P2) in the audiovisual condition, for back oriented stimuli. The x axis represents 4 different auditory stimuli, of decreasing difficulty, from A (the most masked) to D (less masked) . The y axis represents the percentage of "front" answers. As the auditory stimulus becomes easier, participants diminish the number of errors. The dashed lines present the MLI prevision curves for each participant, based on the unimodal results.



10th International Multisensory Research Forum

DAY 2 - TUESDAY

CROSSMODAL PREDICTION DURING PERCEPTION OF AUDIOVISUAL SPEECH

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Information about past events can be used to make predictions about what is coming next. For instance, human perception capitalizes on this type of predictive coding to speed up information processing in a variety of domains, including vision and speech perception. The present study addressed whether predictive coding can occur across sensory modalities. In particular, we hypothesized that input in one sensory modality (i.e. an auditory speech stream) might contribute to predictions about upcoming events in a different sensory modality (i.e. the video of a speaker's face). To test this we used an audio-visual speech-matching task, in which observers made speeded classifications of spoken sentence fragments as either matching or mismatching the moving face seen in a video. We provided prior context to the combined audio-visual fragments using only one of the modalities (i.e., lead-in was audio or video alone) so that the test fragment could be experienced as a continuation of the lead-in. We tested for predictive abilities in both auditory-to-visual and visual-to-auditory directions. The results supported the existence of both within and cross-modal predictions. However, asymmetries were also observed, such that predictions based on audio information alone impaired performance in the speeded matching task whereas predictions based on video information alone lead to improvements.

Multi-modal versus modality-specific activation within the "what" and "where" processing streams for sounds and vibro-tactile stimuli

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The segregation between cortical pathways for the identification and localization of objects is thought of as a general organizational principle in the brain. Yet, little is known about the uni- versus multi-modal nature of these processing streams. The main purpose of the present study was to test whether the auditory and tactile dual pathways converged into specialized multisensory brain areas. We used fMRI to compare directly in the same subjects the brain activation related to localization and identification of comparable auditory and vibro-tactile stimuli. Results indicate that the right inferior frontal gyrus (IFG) and both left and right insula were more activated during identification conditions than during localization in both touch and audition. An inverse dissociation was found for the left and right inferior parietal lobules (IPL), the left superior parietal lobule (SPL) and the right precuneus-SPL, which were all more activated during localization conditions in the two modalities. We propose that specialized areas in the right IFG and the left and right insula are multisensory operators for the processing of stimulus identity while parts of the left and right IPL and SPL are specialized for the processing of spatial attributes independently of sensory modality.

Turning the body inside-out: localization of force feedback beyond bodily boundaries induced by multisensory visuo-tactile conflict

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Force feedback is processed by an interaction of proprioceptors located in the muscles, and so forth represents the most inner perception of the human body. In the present work we demonstrate for the first time ever that such proprioceptive perception, internal as it is, may be allocated outside and beyond bodily boundaries. Multisensory integrative processes related to direct visual influence on early primary somatosensory cortex, or indirect, motor cortex relayed, visual influence on early primary somatosensory cortex are discussed as putative neuronal substrate for the observed phenomenon. The role of parietal associative areas such as the intraparietal sulcus is also debated. Such study sheds light upon differential mechanisms that may contribute to the construction of human body representation.

Modulations of early visual evoked potential in the profoundly deaf

Davide Bottari [1], Anne Caclin [2], Marie-Hélène Giard [2], Francesco Pavani [1]

[1]University of Trento, [2]INSERM

Behavioural studies have revealed enhanced reactivity to visual events in the profoundly deaf. Here we examined the electrophysiological response to visual stimuli in deaf individuals and hearing controls during a speeded simple-detection task. After the appearance of a warning-signal (500ms), a visual target was randomly presented with either a short (500ms) or long ISI (1800ms), at central (3°) or peripheral (8°) locations with respect to fixation. Behaviourally, deaf were faster than hearing controls (on average 40ms), particularly for targets appearing at short ISI. In addition, controls responded more slowly for peripheral than central targets, whereas this difference did not emerged for the deaf. The ERPs revealed sustained activation at occipito-parietal sites in the deaf, before any visual stimulation. Moreover, the C1 component in response to the warning-signal peaked earlier in deaf than controls. Deaf also displayed prolonged and ampler visual analysis in the second phase of the P1 component (showing a marked second peak), which in turn produced a delay of the N1 onset. A comparison of potential and SCD suggests that the second phase of the P1 component in the deaf has deep generators. In addition, while the P1 was ampler for central than peripheral targets in the controls, comparable P1 amplitude emerged in the deaf regardless of target location. Finally, CNV preceding targets at short ISI had a larger amplitude range in deaf than controls. These results show for the first time changes in the dynamic of the very early visual-evoked potentials (C1, P1) in deaf individuals. Because modulation of the late P1 complex has been recently linked to exogenous attention capture, these findings point to a key role of this attentional component in enhanced reactivity in the deaf.

Network Analyses of Multisensory Processing

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The brain is a complex network and multisensory processes occur within the framework of this highly integrated system. While most traditional studies have evaluated unisensory and multisensory brain regions in isolation, a more comprehensive understanding of multisensory processes will be achieved through studies of the brain as a complex network. Since the discovery of small-world 1 and scale-free2 networks studies of complex networks have emerged in virtually every scientific discipline. Small-world networks have the unique property that all elements (vertices or nodes) in the network are within a few links (edges) of each other but maintain high clustering between neighboring elements 1. Scale-free networks have nodes that have an extraordinarily high number of connections (hubs) and a distribution of connections that follows a power law 2. The brain is known to exhibits regional specificity and distributed processing. In the past several years investigators have begun to evaluate the structural and functional connectivity of the brain using network tools and have repeatedly demonstrated that the brain is a small-world network with specific regions serving as the network hubs. Most studies have evaluated the brain at rest and no studies to date have examined network properties under various multisensory conditions.

The current study was designed to evaluate network properties in the human brain under various multisensory conditions. Functional MRI (fMRI) data were collected from 14 subjects while they viewed a fixation point, watched a silent movie, and watched a movie with a sound track. Functional imaging was acquired based on the blood oxygenation dependent level (BOLD) signal using echo-planar imaging (EPI). Networks were generated by performing cross-correlation analyses (functional connectivity) of the temporal signal between each voxel across the entire brain image. This analysis generated a correlation matrix that contained 400 million cells for each subject. A threshold was applied to each matrix based on the correlation coefficient to generate binary adjacency matrix. Global properties such as clustering coefficient, path length, and degree distributions were compared across stimulus conditions. In addition, the location of connector hubs and community structure were assessed. The global network metrics did not reveal differences between sensory conditions indicating that the network did not exhibit overall organizational changes across the stimulation conditions. However, changes in the local network properties were consistently revealed. Brain hub structure exhibited spatial changes with hubs in the default-mode network at rest. The hubs were significantly increased in visual cortex during the silent movie and in visual and auditory cortices during the multisensory movie. The community structure analysis revealed interesting findings in sensory cortex. During viewing of the silent movie the somatosensory and auditory cortices were clustered into a single neighborhood likely due to suppressive effects from visual attention. During the multisensory movie the community structure changed and auditory cortex became a highly organized and localized neighborhood. The data demonstrated that network analyses provide a unique and powerful method for evaluating multisensory processes. Identification of network neighborhoods that dynamically change with sensory conditions reveals the functional organization associated with multisensory processing.

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Visual-Vestibular Cue Combination during Temporal Asynchrony

Jennifer L. Campos, John S. Butler, Heinrich Bülthoff

Max Planck Institute for Biological Cybernetics

Currently little is known about the principles underlying human visual-vestibular integration during self-motion. Previous work from our lab has shown that 3D visual information combines with vestibular cues in a statistically optimal fashion, even when spatial offsets between the two cues are introduced. In this experiment we extended this research question by evaluating the effects of creating temporal offsets between visual and vestibular cues during a heading judgment task. This experiment was conducted using a Stewart motion platform equipped with a 90 degree, wide field-of-view projection screen. Participants were presented with a linear, diagonal movement and asked whether they were heading in a rightward or leftward direction relative to their starting position. Self-motion information was either presented via visual cues alone, vestibular cues alone, or both cues combined. In the combined condition the two cues were either congruent (1/7 trials) or incongruent in their temporal order. The temporal offsets ranged from -0.5 s (visual motion started before vestibular motion) to +0.5s (vestibular motion started before visual motion). The temporal offsets were presented in a random order and participants completed 6 daily sessions of 1.5 hours each. Results demonstrate that, for the first half of the trials, the highest variance was observed in the extreme temporal offset trials (+/- 0.5s). However, for the last half of the trials, the highest variance was actually observed in the congruent cue trials, with the lowest variance observed for the extreme temporal offsets. These findings indicate that, the way in which visual and vestibular information is combined changes dynamically as a function of increased exposure to discrepant cue information.

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A helping hand: an enhancement of the visual response by skin region

Joshua N Lucan, John J Foxe, Sophie Molholm

The City College of New York

Regions of the parietal and premotor areas of the neocortex have been identified which respond to both somatosensory and visual stimuli with overlapping receptive fields. It has been hypothesized that the number of these bisensory neurons which respond to a purely visual stimulus corresponds to the number of somatosensory receptors which innervate the skin region on which the stimulus appears (Brown et al., 2008). Here we show a modulation of the visually evoked potential in humans by manipulating the skin type on which visual stimuli appear. Spatial gratings projected onto the more densely innervated palm of the hand resulted in enhanced responses across the P1-N1 timeframe (100 -250 ms) over those projected onto the less densely innervated back of the hand.

DAY 2 - TUESDAY

Assessing the implicit association between sour food & high-pitched sounds

Anne-Sylvie Crisinel, Charles Spence

Oxford University

Our evaluation of food does not only involve the sense of taste, but is also profoundly influenced by information from the other senses (such as olfaction, vision, touch, audition, and the trigeminal sense). Among these multisensory interactions, the existence of auditory influences on taste perception is the one that has been treated most sceptically (Delwiche, 2004), and has garnered the least scientific interest (though see Spence, Shankar, & Blumenthal, in press). However, Beeli et al. (2005) recently reported a case study of an in individual exhibiting synaesthesia between sounds and tastes. 'Normal' people's perception of the crispness of potato chips has also been shown to be altered when the auditory feedback from the biting sound is modified (Zampini & Spence, 2003). The aim of the present study was therefore to explore the possible association between specific tastes (bitter and sour) and specific auditory stimuli. A version of the Implicit Association Test (IAT, Greenwald et al., 1998) was used, in which we evaluated the strength of the association between sour or bitter food or drinks and high-pitched or low-pitched sounds (see Table 1). The association between sour taste and high-pitched notes (and bitter taste with low-pitched notes) was stronger than the reverse one, as revealed by the faster reaction times (RTs) observed when the same key was used for both categories. This association wasn't influenced by taster status, as measured by a PTC tasting test. Our results suggest that gustatory perception is not only influenced by food attributes, such as smell, colour, and texture, but also by other types of sensory information.

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DAY 2 - TUESDAY

Visual Orientation and Navigation in 3D space: Active manual control countermeasures

Martine Godfroy [1], Joel Miller [2], Patrick MB Sandor [3], Bernard D. Adelstein [2]

[1]California State University at San Jose, [2]NASA Ames Research Center, [3]Imassa

The goal of the present study was to investigate how different manual input devices interact with spatial cognition in single or double-step transitions in an operational navigation aeronautical environment. The first step consisted in subjects performing an active trajectory modification followed by the automated reorientation of the updated flight path in reference to the initial viewpoint. The second step, when applying, consisted in a second transformation that could be either a translation (from Central to Temporal or vice versa) or a tilt of the viewpoint (2D to 3D or vice versa).

The results show an effect of the initial viewpoint, as well as an effect of translation on the performance. The effect of input devices on spatial memory (as measured by accuracy) showed to be dependent upon the amplitude of the deviation between initial and final ownship positions, suggesting an effect of manual control.

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Perceptual weight judgments when viewing own and other's movements under minimalist conditions of visual presentation

Malika Auvray, Thomas Hoellinger, Sylvain Hanneton, Agnes Roby-Brami

Laboratory of Neurophysics and Physiology, CNRS UMR 8119

The impressive visual sensitivity to human movements is illustrated by the ability to recognize actions even when the whole body movements are reduced to the movements of a few point-lights. Across 3 experiments, we investigated the role of the conditions of visualization and ownership in perceptual weight judgment tasks. The observers were displayed minimal information on movements consisting of either the working point displacement only or additional configural information on the kinematics of the trunk, shoulder, arm, forearm, and hand joined by a stick diagram. Furthermore, the participants were displayed either their own movements or those of another participant while lifting different objects' weight. The results revealed that although participants' overall performance was not dependent on the conditions either of visualisation (working point vs. stick diagram) or ownership (self vs. other), the kinematic cues used to perform the task (i.e., mean acceleration, maximal height, maximal velocity, duration of the phases of movement: reach, grasp, lift, and place) differed as a function of these conditions. In addition, the results revealed that the kinematic parameters that are relevant for action observation do not entirely match the ones that are relevant for action execution. We discuss the implications of these results for our understanding of action observation in terms of the opposing motor simulation and visual analysis hypotheses.

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The "Continuum Hypothesis:" Different patterns of multisensory convergence generate a range of multisensory neurons

Brian L Allman, Leslie P Keniston, M. Alex Meredith

Virginia Commonwealth University School of Medicine

Traditionally, neuronal studies of multisensory processing are conducted first by selecting overtly multisensory (e.g., bimodal, trimodal) neurons and then testing them. This paradigm risks overlooking multisensory neurons that lack overt multisensory properties. Therefore, the present study examined, without selection bias, neurons in several cortical areas for their responses to separate (e.g., visual, auditory, somatosensory) and combined-modality (e.g., visual and auditory, auditory and somatosensory, etc.) stimulation. As expected, traditional bimodal forms of multisensory neurons were identified. In addition, however, many neurons that were activated only by one modality of stimulation (i.e., unimodal) had that response modulated by the presence of an auditory stimulus. Some unimodal neurons showed multisensory responses that were statistically different from their response to an effective unimodal stimulus. Other unimodal neurons had subtle multisensory effects that were detectable only at the population level. These results expand the range of multisensory convergence patterns beyond that of the classical bimodal neuron. However, rather than characterize a separate class of multisensory neurons, unimodal multisensory neurons may actually represent an intermediary form of multisensory convergence that exists along the functional continuum between unisensory neurons, at one end, and fully bimodal neurons at the other.

Symposium 3: An embodied view of multisensory speech

10:30-12:30

Organised by Asif A Ghazanfar, Princeton University

Chair: Asif Ghazanfar

Speakers:
Kevin Munhall, *Queens University*

David Ostry, *McGill University*

Charlie Schroeder, *Nathan Kline Institute & Columbia University*

Asif A Ghazanfar, *Princeton University*

Overview:
When two people talk, we listen to each other's words, and even visually process the facial movements, but a deep level of the communication goes much beyond that. It involves watching gaze and body posture and facial expressions as the words are being said. Indeed, how we hear and see is further influenced by our own bodily states. Thus, the meaning of a speech act is situated both in the body and in the social context, and this meaning engages neural processes that guide the subsequent actions of the interlocutors.

While the idea that communication is embodied and situated is widely acknowledged, there have been few attempts to bridge the epistemic gaps between different approaches to this problem. The aim of this symposium is to make an effort to close these gaps. We will present data which reveal the multiple levels and timescales that multisensory speech operate on, and show that the behavioral and neural levels potentially operate as unified, resonant system between at least two communicating individuals.

Symposium 3: An embodied view of multisensory speech

Temporal patterns in spoken language

Kevin G. Munhall

Queen's University

Kevin will present work on the different spatial and temporal scales on which visual and multisensory speech perception operate. Take one example: People naturally move their heads when they speak, and this rhythmic head motion conveys linguistic information. Head movements correlate strongly with the pitch and amplitude of the talker's voice and perceivers can better detect speech in noisy situations when natural head motion is present.

Symposium 3: An embodied view of multisensory speech

Somatosensory function in speech motor learning and perception

David J. Ostry

McGill University

David will review data showing that somatosensory signals from the facial skin and muscles of the vocal tract provide a rich source sensory input in speech production. This somatosensory input is important in guiding both speech motor learning and speech perception.

Symposium 3: An embodied view of multisensory speech

Mechanisms and Significance of Multisensory Influences in Unisensory Cortices

Charles E. Schroeder

Nathan Kline Institute & Columbia University

Charlie will present data supporting the hypothesis that the enhancement effects of vision on the perception speech operate through the ongoing oscillatory activity of local neuronal ensembles in the primary auditory cortex. These oscillations are 'predictively' modulated by visual input, so that related auditory input arrives during a high excitability phase and is thus amplified.

Symposium 3: An embodied view of multisensory speech

Vocal communication through coupled oscillations

Asif A. Ghazanfar

Princeton University

Asif will review work which suggests that the temporal structure of auditory and visual communication signals matches, and perhaps resonates with, the structure of on-going oscillations in the temporal lobe. Specifically, the low frequency theta rhythm seems to be a key feature in linking both signalers and receivers in a communicative exchange.

Symposium 4: Graduate student award talks

1:30 – 3:30

1:30 – 1:45

Amputees 'neglect' the space near their missing hand

Tamar R Makin [1], Meytal Wilf [1], Isabella Schwartz [2], Ehud Zohary [3]

[1]Neurobiology Department, Hebrew University of Jerusalem
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[3]Neurobiology Department and Interdisciplinary Center for Neural Computation, Hebrew University of Jerusalem

Action space, the space within reach of our hands, provides a medium for our constant interaction with the world. We hypothesized that hand-amputation, producing an asymmetry in action space, would cause permanent distortions in visuospatial perception. We report here that hand-amputation is associated with a mild visual 'neglect' of the amputated side: Amputees favored the intact side when comparing distances in a position-judgment task. This bias was absent when the targets were placed in far space. We suggest that near-space hemineglect, which is often coupled with left-hand paralysis, may be exacerbated by a similar asymmetry in action space.

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Symposium 4: Graduate student award talks

1:45 -2:00

Visual influences on voice-selective neurons in the anterior superior-temporal plane

Catherine Perrodin [1], Christoph Kayser [1], Nikos K. Logothetis [1], Christopher I. Petkov [2]

[1]Max Planck Institute for Biological Cybernetics, [2]Institute of Neuroscience, Newcastle University Medical School

For social interaction and survival primates rely heavily on vocal and facial communication signals from their conspecifics. To date many studies have evaluated the unisensory representations of either vocal or facial information in regions thought to be "voice" or "face" selective. Other studies have directly evaluated the multisensory interactions of voices and faces but have focused on posterior auditory regions closer to the primary auditory cortex. This work investigates multisensory interactions at the neuronal level in an auditory region in the anterior superior temporal plane, which contains one of the important regions for processing "voice"-related information.

Extracellular recordings were obtained from the auditory cortex of macaque monkeys, targeting an anterior "voice" region that we have previously described with functional magnetic resonance imaging (fMRI). For stimulation we used movies of vocalizing monkeys and humans which we matched in their low-level auditory and visual features. These dynamic face and voice stimuli allowed us to evaluate how neurons responded to auditory, visual or audio-visual components of the stimuli. Our experiments also contained control conditions consisting of several mismatched audiovisual stimuli combinations, such as 1) a voice matched to a face from a different species, 2) adding a temporal delay in the visual component of the stimulus, or 3) using an acoustically manipulated voice with the original facial stimulus.

Our neuronal recordings identified a clustered population of voice-selective sites in the anterior superior temporal plane, ~5 mm anterior to field RT. A significant visual influence of the dynamic faces on the

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corresponding ("matched") vocalizations was observed in both the local-field potential (LFP) and the spiking activity (analog multiunit activity, AMUA): 38% of the sites showed audiovisual interactions in the LFP signals, and 60% in the AMUA. In addition, the multisensory influence was significantly stronger for the matching voice and face stimuli than to any of the incongruent ("mismatched") control conditions, confirming the specificity of the cross-sensory influence on the neuronal activity.

Our results provide evidence for visual influences in what has been characterized as an auditory 'voice' area. This visual modulation was specific for behaviorally relevant voice-face associations and demonstrates that the processing of voice related information in higher auditory regions can be influenced by multisensory input.

Symposium 4: Graduate student award talks

2:00 – 2:15

Distinct temporal lobe projections to auditory and visual regions in the ventral prefrontal cortex support face and vocalization processing

Maria M Diehl, Jennifer Bartlow-Kang, Tadashi Sugihara, Lizabeth M Romanski

University of Rochester, SMD

The integration of face and voice information is required for communication in human and non-human primates. The purpose of this study was to examine connections between the auditory and visual responsive regions in the ventrolateral prefrontal cortex (VLPFC) and specific regions of the temporal lobe. Previous studies have shown that neurons within area 45 of the VLPFC are responsive to pictures of complex visual stimuli, including faces, while adjacent area 12/47 contains cells that are responsive to complex auditory stimuli including species-specific vocalizations. Furthermore, when face and vocalization stimuli are presented simultaneously, multisensory, audiovisual responses can be elicited from some VLPFC neurons within these same regions. We asked whether these different physiologically responsive regions of prefrontal cortex might also receive a different complement of afferent input from the temporal lobe which would convey the different selectivity to audio-visual stimuli.

We recorded auditory, visual, and multisensory responsive neurons from VLPFC. After determining the boundaries of the auditory, visual, and multisensory-responsive regions, we placed distinct anatomical tracers into each location. This would allow us to determine the different patterns of afferent and efferent connections of each of these functionally distinct VLPFC regions. Our results demonstrate that prefrontal auditory neurons receive the densest input from superior temporal gyrus (STG) areas TAa, the anterior parabelt, and to a lesser extent area TPO. In contrast, visually responsive neurons in VLPFC receive afferent projections from a number of inferotemporal cortex areas including TE, IPa, PGA and TPO. Injections placed into regions

where neurons responded to both auditory and visual stimuli resulted in labeling mainly in TPO and to a lesser degree areas TAa, IPa, and TE. Finally, all of our injections resulted in retrograde labeling of the amygdala and anterograde labeling of the striatum. By investigating the anatomical connections of the VLPFC, we hope to better understand how auditory and visual information reaches the frontal lobes. The information gained from our tracing studies may provide clues about the neural circuit that underlies integration and processing of communication information.

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Symposium 4: Graduate student award talks

2.15 – 2.30

Motion aftereffects transfer between touch and vision

Talia Konkle [1], Qi Wang [2], Vincent Hayward [3], Christopher I Moore [1]

[1] McGovern Institute for Brain Research & Department of Brain & CognitiveSciences, MIT, [2]Department of Biomedical Engineering, Georgia Institute of Technology [3]Institute des Systèmes Intelligents et de Robotique

Motion can be experienced through both the visual and tactile modalities, and recent neuroimaging findings demonstrate that visual motion processing regions (e.g MT+) can be activated by tactile stimuli. While most studies find visual motion dominates tactile motion judgments during concurrent stimulation, if common substrates support visual and tactile motion processing independently, then crossmodal influences should exist under conditions of non-concurrent stimulation. To test the relationship between visual and tactile motion processing, we examined the transfer of motion aftereffects. We found that repeated exposure to visual motion in a given direction produced a tactile motion aftereffect, the illusion of motion in the opponent direction across the finger pad. We also observed that repeated exposure to tactile motion induced a visual motion aftereffect, biasing the perceived direction of counterphase gratings. These crossmodal aftereffects, operating both from vision to touch and from touch to vision, present strong behavioural evidence that the processing of visual and tactile motion rely on shared representations that dynamically impact modality-specific perception.

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Symposium 4: Graduate student award talks

2:30 – 2:45

Multisensory Integration in Prelingually Deafened Adults with Cochlear Implants

Julie M Verhoff [1], Lynne E Bernstein [1, 2, 3]

[1]Gallaudet University, [2]House Ear Institute, [3]University of SouthernCalifornia

Prelingually deafened adults, that is, individuals who were either born deaf or lost their hearing prior to learning language, are typically not considered to be good candidates for a cochlear implant (CI) because their performance on auditory-only (AO) speech perception tests is significantly lower than is performance on the same tests by postlingually deafened adult CI recipients. However, AO word and sentence recognition scores do not fully represent the benefit from a CI, because degraded acoustic input can be integrated with visual speech information. A fundamental question is the extent to which integration is possible in individuals who have experienced lifelong impoverished or distorted auditory input. Eighteen prelingually deafened adult CI users (21 to 55 years of age) with at least six months of experience using their implant, and English as their primary language, were tested on several measures of unisensory and multisensory perception. Participants were implanted in adolescence or as adults (13 to 55 years of age at implant). One of their tasks was open-set sentence identification under AO, visual-only (VO), and audiovisual (AV) conditions. Stimuli were in lists of sentences with equal expected mean scores. The participants responded to each sentence by typing on a computer keyboard the whole sentence or any words or parts of words they understood. Fourteen participants had good or excellent levels of AV integration. Their mean percent words correct scores were VO, 31% (range, 15-58%), AO, 27% (range, 1-74%), and AV, 67% (range, 16-91%). However, four participants demonstrated little integrative ability. Their mean percent words correct scores were VO, 15% (range, 7-29%), AO, 18% (range, 0-72%), and AV, 36% (range, 19-74%). Participants were also tested on detection of a spoken acoustic "ba" [1] within an external noise paradigm [2] at four fixed noise levels (i.e., no noise; and 20, 40, and 60dB SPL white noise). A two-alternative fixed-choice adaptive staircase method was used in which the acoustic signal level was varied to obtain the 79.4% correct detection thresholds. Four conditions were tested, (1) AO, (2) audio with a vibrotactile pulse-train stimulus (AT), (3) audio with a rectangular visual stimulus (AVR), and (4) audio with visual speech (AVS). Two independent sources of potential multisensory threshold improvement were modeled, a sensory reduction in intrinsic noise and an increase in sampling efficiency. Intrinsic noise is the inherent noise in the sensory system and is theoretically stimulus-invariant. Efficiency is a measure of task-relevant stimulus information utilization. Results showed that multisensory detection efficiency was higher than AO efficiency but generally lower than comparable efficiencies of normal-hearing adults. Thus, the high levels of integration in the AV spoken sentence test were dissociated from the efficiencies in the detection paradigm. As might be expected, intrinsic noise was higher than normal. These results suggest that integrative multisensory enhancements in this prelingually deaf population vary as a function of the task. Research supported by NIH/NIDCD DC008308.

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Symposium 4: Graduate student award talks

2:45 – 3:00

Disrupting spatial remapping of touch with TMS

Elena Azañón [1], Matthew R. Longo [2], Patrick Haggard [2], Salvador Soto-Faraco [3]

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Localizing and reacting to tactile events on the skin requires the coordination of several spatial maps. In particular, since the primary somatosensory cortex represents skin location independently of body posture, the brain must re-align tactile coordinates in order to retrieve the location of events in external space. We have investigated the temporal course of this process as well as its physiological bases.

In a first (psychophysical) experiment, participants held their arms crossed and performed a discrimination task on lateralised visual targets presented near the hands, after receiving a non-predictive tactile cue on the same or different hand. During the first hundred milliseconds after the tactile cue, reaction times were speeded up for anatomically congruent but spatially incongruent visual targets. This pattern reversed at longer cue-target intervals, so that tactile cues now produced a facilitation of visual targets presented at the same external location. These results reveal the time course of the dynamic remapping of tactile space, with early somatotopic representations, reflecting the neural organization in SI, giving way to the later external frame of reference that characterizes our everyday life experience. From the time course of the cueing effects as well as previous findings, we reasoned that some structures in the posterior parietal cortex (PPC) may be critical for this tactile remapping.

In a second experiment we therefore aimed to disrupt processing in the PPC during remapping using TMS. We designed a tactile remapping task involving unilateral stimulation, appropriate for unilateral TMS pulses. Participants held their left arm flexed with the forearm in vertical position, lateral to the face. They were asked to judge whether a tap at one of several forearm locations was higher or lower than a preceding tap at one of several possible locations on their face. Location of the taps on arm and face varied randomly and the arm was passively moved between different vertical positions. Therefore, integration of spatial information from touch and proprioception was necessary to achieve the task. Single pulse TMS was applied at the scalp, targeting the right ventral intraparietal area (VIP) or a control site (vertex), 60 or 250 ms after the arm tap. The Just Noticeable Difference in the elevation judgement task was poorer following VIP TMS than control TMS, suggesting disruption of tactile remapping process. Participants also consistently underestimated the elevation of arm taps (i.e. increased proportion of "down" responses) after TMS in the VIP condition, producing a shift in the point of subjective equality (PSE). A control experiment showed that perceived position of the hand was not affected by VIP TMS, ruling out explanations based on simple proprioceptive masking. Our TMS results indicate that parietal disruption selectively impairs remapping of touch into egocentric space. The effects of PSE in the VIP condition are discussed in terms of reversion of the body schema towards a canonical arm position.

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Symposium 4: Graduate student award talks

3:00 – 3:15

The Development of Multisensory Facilitation in Children and Early Adolescence

Ayla Barutchu [1, 2], Hamish Innes-Brown [2], Sheila Crewther [3], Mohit Shivdasani [2], David Crewther [4], Antonio Paolini [1],

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[3]School of Psychological Science, La Trbe University, [4]The Brain Sciences Institute, Swinburne University of Technology

The development of audiovisual facilitation of motor responses to concurrent audiovisual stimuli in school age children has not been previously reported. Thus, this study investigated multisensory integration in late childhood and early adolescence at both a behavioural and neural level. Motor reaction times (MRTs), accuracy and high-density electroencephalography (64 scalp electrodes, sampling rate: 488 Hz, filter bandpass: 2.6 – 100 Hz at 12 dB/Oct) were recorded while children, adolescents and adults performed an audiovisual detection task. Stimuli included auditory (AT), visual (VT), audiovisual (ATVT) targets and blank invalid trials presented in a random order for the duration of 40 ms. All 3 age groups were faster at detecting the ATVT stimulus compared to AT and VT stimuli. Cumulative density functions (CDFs) of MRTs demonstrated that discrepancies between ATVT CDFs and AT+VT CDFs were greater for adults than for children or adolescents. Multisensory integration at a neural level was isolated by subtracting the sum of the two unisensory evoked potential from the multisensory evoked potential (ATVT–[AT+VT]). Multisensory integration observed at 100 ms post stimulus onset was distributed over occipital-parietal electrode sites in children and adolescents and more localised to occipital electrode sites in adults. Both behavioural and electrophysiological measures suggest that multisensory integration is immature beyond late childhood and early adolescence. Dissimilarity in topographic distribution of multisensory neural processes in children, adolescents and adults may be associated with differences in cortical myelination and organization, which continue to mature until early adulthood.

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KEYNOTE ADDRESS
3:30 – 4:30

The organization of modules in posterior parietal cortex of primates for specific sensorimotor functions

Prof. Jon Kaas, Iwona Stepniewska, Omar Gharbawie

Vanderbilt University

Posterior parietal cortex of primates has long been known to have sensorimotor functions mediated in part by sensory inputs and outputs to motor and premotor areas of frontal cortex. Our research takes advantage of the fact that stimulation of sites in posterior parietal cortex with relatively long trains of electrical pulses evokes different classes of complex movements from different modular regions, and that similar regions exist in motor and premotor cortex. Such regions exist in prosimian primates, New World monkeys, Old World monkeys, and probably all primates. Regions for grasping with the forelimb, aggressive movements, defensive movements, and reaching have been found in prosimian galagos, squirrel monkeys, and owl monkeys. While posterior parietal cortex of macaque monkeys has been less extensively studied, grasping and defensive regions have been detected. The sequence of these specific modules is similar across studied primates, but they course lateromedially within the anterior half of posterior parietal cortex in prosimian galagos, and more from anterior to posterior in monkeys. Another difference is that the motor behavior modules in posterior parietal cortex of galagos receive little direct visual information from visual cortical areas, but instead receive more processed visual inputs from the posterior half of posterior parietal cortex. The modules in all these primates also receive dense inputs from areas of somatosensory cortex, and possibly higher order auditory inputs. Posterior parietal modules connect selectively with regions of motor and premotor cortex where similar complex movements can be evoked. Movements are no longer evoked from posterior parietal cortex when the functions of the relevant parts of motor cortex are blocked. The results support the conclusion that posterior parietal cortex of primates contains a number of functionally distinct zones where complex movements that are ethologically relevant can be evoked. These zones are parts of different cortical networks that involve different combinations and types of sensory inputs for guiding motor behavior via different combinations of outputs to motor and premotor areas of frontal cortex.

DAY 2 - TUESDAY

Oral Session 2: Body Schema
4:30 – 5:30

4:30 – 4:50

The effects of arm and eye position on the perceived location of touches on the arm

Vanessa Harrar, Laurence R Harris

Department of Psychology, Centre for Vision Research, York University, Toronto

Introduction: The perceived position of auditory and visual stimuli shifts with head and eye position. Recently it has been shown that touches on the body also appear shifted when the head and eyes are not aligned indicating a coding system for touches that depend on the position of the eyes in the head. However, previous experiments that found eye position effects on localizing tactile and auditory stimuli required subjects to report the location of the stimuli in visual coordinates (relative to some visual scale). The transforms required by this method may have contributed to the effect of eye position reported. Therefore, we determined the effect of independently varying visual, arm, and body reference frames on the perceived location of touches using a novel technique that requires subjects to locate the position of touches relative to the arm. Methods: Eye position was controlled by having subjects fixate one of four lights separated by 10° arranged from left to right. Subjects' left arms were placed over four tactors which were separated by 5 cm. The subject's arm was positioned in one of three different orientations relative to their body: across the body, straight out (away from the body), or stretched out to the side. We drew lines on each subject's forearm, dividing it into four equal segments, and asked subjects to report the segment (1-4) in which they were touched. This task did not require subjects to transform the touch into visual space. Results: As the eyes moved from left to right, the segment of arm in which a given touch was reported, shifted towards the wrist (for the left arm). The magnitude of the shift was smaller when measured in body coordinates than previously reported using a visual measure. The orientation of the arm relative to the body did not have a significant effect on the amplitude or direction of the eye-position-related shift. The perceived locations of the touches also varied with arm position. For both arm- and eye-related shifts, not all the areas of the arm were affected equally. Conclusions: Shifts of the perceived locations of touches related to eye position indicate that touches might be coded in a visual reference frame. The lack of systematic errors associated with arm position suggests that there are no additional localization errors associated with updating the position of the arm in space for judgments made in body coordinates. A comparison of tactile localization judgments made in visual versus body coordinates will be discussed and a model for tactile spatial perception will be presented.

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DAY 2 - TUESDAY

Oral Session 2: Body Schema

4:50 – 5:10

Tool-use induces functional updating of the body schema

Lucilla Cardinali [1], Francesca Frassinetti [2], Claudio Brozzoli [1], Christian Urquizar [1], Alice C. Roy [3], Alessandro Farnè [1],

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To control bodily movements the human brain relies on a somatic representation termed body schema (BS). The almost one-century-old hypothesis that tool-use induces plastic changes resulting in the tool being incorporated in the BS is nowadays widely accepted. Whether tool-incorporation truly occurs remains unknown, however, as tool-use has never been shown to affect ensuing arm motor behavior. Here we report that using a mechanical grabber that physically extends the arm, alters the kinematics of subsequent free-hand grasping movements. Consistent with incorporation of the tool length in the BS, the tool-use-dependent differences in kinematics fit those naturally existing when comparing actions performed by subjects with longer vs. shorter arms. Remarkably, the tool-use after-effect was shown to generalize to pointing movements, despite no specific tool-training. These findings not only provide the first evidence that tool-use alters the body schema, but also reveal that what is modified is the somatic representation of intrinsic properties of the body morphology.

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Oral Session 2: Body Schema

5:10 – 5:30

Having a body versus moving your body: neural signatures of body-ownership and agency

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Body ownership can be easily confused with the sense of controlling one's body because agency is a powerful cue to ownership: my body feels like 'mine' in part because I can control it at will. As a result, interactions between body-ownership and agency are difficult to investigate. A first imaging study using PET reveals that the right posterior insula that has been previously linked to agency, may in fact encode body-ownership. Because agency typically involves both efferent and afferent signals, previous studies have been unable to distinguish between these alternatives. We therefore developed an fMRI paradigm to investigate multisensory and sensorimotor aspects of body representation in the brain in an attempt to disambiguate the neural signatures of agency and body-ownership. Movements of the participant's hand were either self-generated or externally-generated, and video-feedback was relayed either in real-time or with a systematic delay. Analyses showed different activations in the right parietal lobe for intersensory and sensorimotor conflicts. Activity in the SMA was linked to a sense of agency distinct from the sense of body-ownership, while activations in midline cortical structures were associated with a purely sensory-driven sense of body-ownership. The results are discussed in the light of recent neurocognitive models of self.

DAY 2 - TUESDAY

Day Three

Wednesday July 1st 2009

8:30–9:00	**Registration**
9:00–10:30	**Posters III (coffee/snack)**
10:30–12:30	**Symposium 5: The development of multisensory integration - chaired by David Lewkowicz**
12:30–2:00	**Lunch – buffet style at quad**
2:00–4:00	**Oral Session 3: Development**
4:00–4:30	**Coffee/snack**
4:30-5:30	**Keynote 3 – Nikos Logothetis**
5:30–7:00	**Break and travel time to banquet dinner**
7:00-10:00	**Banquet dinner at Battery Garden Restaurant**

Posters III
July 1st 2009
09:00 – 10:30

Two opposing mechanisms in the calibration of simultaneity in temporal order judgments

Shinya Yamamoto [1], Makoto Miyazaki [2], Takayuki Iwano [1, 3], Shigeru Kitazawa [3]

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After repeated exposure to a pair of audiovisual stimuli with a constant lag, subjects eventually judge the pair as occurring simultaneously (lag adaptation). In contrast, perceptual changes occur in the opposite direction with tactile stimuli, delivered one to each hand, which conforms to a Bayesian integration theory. Several recent studies have examined the calibration of simultaneity in regard to sound and touch, and light and touch, but results remain at odds with each other. These findings may seem confusing, but they become more reasonable assuming that both mechanisms operate in the brain. We previously showed, in theory, that the effect of Bayesian calibration cannot be observed when the lag adaptation was fully operational. This led us to hypothesize that Bayesian calibration is at work even during judgments regarding audiovisual temporal order, but that the effect is concealed behind the lag adaptation mechanism. In our recent study, we have shown that this was the case. By "neutralizing" lag adaptation by using two pitches of sounds, we successfully uncovered Bayesian calibration that was working behind lag-adaptation. From the results and the theoretical considerations, we propose a serial model that combines lag adaptation and Bayesian calibration and suggest that the size and direction of shift in the point of simultaneity ranges from full lag adaptation to full Bayesian calibration, depending on the strength of lag adaptation.

Multimodal Bayesian combination of visual information about object size with observation of an actor: cue integration by the mirror neuron system?

Monica Gori [1], Allessandra Sciutti [2], Giulio Sandini [1], David Burr [3]

[1]IIT Istituto Italiano di Tecnologia, [2]IIT-DIST, [3] Università di Firenze

Purpose of the study: Recent results suggest that humans can integrate optimally information from multimodal systems. In this study we investigated whether a) optimal visuo-haptic integration can extend outside the haptic workspace; and b) if integration can occur between our visual signals of object size with those resulting from observing an actor grasping the object.

Methods: We measured size discrimination of physical spheres of different diameter (varying around 50 mm), positioned at varied distances from the subjects (42-120 cm). In the first experiment subjects reported (in 2AFC) which of two spheres appeared bigger, using only visual information. The standard was always presented at 60 cm distance, while the comparison could be positioned at the same or different distance (in random order). In separate sessions, we asked subjects to match with their index and thumb the dimension of a sphere, and measured by Optotrak aperture between the two fingers. The size discrimination judgement and the matching task were afterwards repeated in three other conditions: subjects observe the spheres, and also an actor reaching to and grasping the object; an actor reaching to and touching the object; or a static hand holding the object. We also measured performance with conflicting visuo-haptic information, to evaluate the integration.

Results: Our results show that subjects overestimate object size for distances larger than their haptic workspace. The bias was also observed when subjects responded by matching their grip size. Interestingly, the bias decreased and precision improved when subjects observed an actor grasping: the control conditions (pointing and static hand) had little or no effect.

Conclusion: Our results suggest that object outside the haptic workspace are perceived larger than they should be, increasing as a function of distance. However, this internal bias can be reduced by observing of an actor grasping the object. The Bayesian ideal-integration model predicts well both the abolition of overestimation, and the improvement in thresholds. We suggest that the "Mirror system" could mediate this process.

What you feel within a move: The spread of tactile attention during goal-directed movements

Georgiana Juravle [1], Heiner Deubel [2], Charles Spence [1]

[1]University of Oxford, [2]Ludwig-Maximilian University, Munich

A considerable body of research (Deubel & Schneider, 1996; Eimer et al., 2005) on motor preparation has shown that shortly before the initiation of a movement, attention is directed at the goal location of the movement. These studies argue in favour of attentional facilitation. On the other hand, research on motor control (Bays et al., 2005; Voss et al., 2006) has provided evidence for tactile attenuation/inhibition shortly before contact with the object is made.

In the present study, we investigated the temporal window of tactile attention changes starting with motor preparation, through motor execution up to the moment of contact with the goal object, as well as the post-contact period. Considering the research that has been published on motor preparation and motor control, we expected that tactile discrimination performance would be facilitated in the motor preparation period and to gradually decline during the motor execution period preceding the contact with the object. Tactile discrimination performance was expected to be facilitated once the object had been grasped.

In order to examine the temporal distribution of tactile attention, we used a dual-task paradigm involving a speeded movement task together with a non-speeded tactile discrimination task. A tactor was attached to the palmar region of the right hand of our right-handed participants, between the thumb and the index finger. Following an auditory signal, they grasped a computer mouse and pressed the left mouse button using their index finger. A second beep instructed participants to reach and grasp for a second mouse placed 25 cm in front of the first one, as well as to press the left mouse button. They were instructed to keep hold of the second mouse until they heard a third beep. Once this last beep was presented, the participants returned to the starting position and gave a response regarding the intensity of a single tactile pulse presented during the trial (participants' discrimination performance -weak vs. strong pulse- was adjusted during a practice session to give 80% correct performance with the hand at rest). The tactile pulse was delivered at various time intervals before, during, and after the movement execution. These results highlight the differential deployment of tactile attention during the course of the prepared movement. We discuss these findings in the light of the different theories of attentional facilitation and attenuation in goal directed movements.

Reference:

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DAY 3 - WEDNESDAY

Crossmodal short-term memory representation of visual and kinaesthetic information

Anna Seemüller, Katja Fiehler, Frank Rösler

Philipps-University Marburg

Crossmodal matching of successively presented objects and shapes relies on a comparison of a stimulus representation with a target. Whereas some studies suggest a translation of modality-specific representations of visual and kinaesthetic stimuli into a representation of the target modality, other findings point to an amodal representation of stimuli. To investigate crossmodal short-term memory representations a unimodal (visual – visual, kinaesthetic – kinaesthetic) and crossmodal (visual – kinaesthetic, kinaesthetic – visual) delayed matching-to sample task was employed. Participants compared two angle-shaped movement trajectories presented either visually as a moving light spot on a screen or kinaesthetically as a passively guided hand movement applied via a manipulandum. To test for a possible translation process an interference task was inserted within the delay (6 sec). During the interference task, a visually or kinaesthetically presented ellipse (interference type), which had to be rated as vertical or horizontal, was shown either at the beginning or in the middle of the delay (interference time). An unfilled delay served as control condition. The results showed no effect of interference type on correct responses or reaction times in the interference task. Therefore, interference task difficulty was comparable for visual and kinaesthetic ellipses. Task performance in the unimodal and crossmodal delayed matching-to-sample task measured as correct responses was better in the control condition than in the interference conditions suggesting that both interference types impaired short-term memory representations. There was no effect of interference type or interference time. Thus, the results indicate an amodal spatial representation of visual and kinaesthetic information in crossmodal short-term memory rather than a recoding of modality-specific representations.

Massive crossmodal reorganization of ferret auditory cortex induced by adult deafness

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Virginia Commonwealth University School of Medicine

Crossmodal reorganization, the phenomenon whereby the responsiveness of sensory areas is converted from a deprived modality to that of an intact sensory system, commonly occurs in response to developmental lesions. Within the adult brain, however, little is known about its capacity for crossmodal remodeling of sensory representations. Therefore, the potential for cortical crossmodal reorganization was examined in ferrets deafened as adults. Seven ferrets (152±32 days old) were rendered profoundly deaf (>90 dB threshold) using a single co-administration of kanamycin and ethacrynic acid. Using standard electrophysiological techniques, recordings from adult-deafened 'auditory' cortex revealed an extensive conversion: neurons once activated by auditory cues were now driven by somatosensory stimulation. This effect was observed within 16 days of deafness. The crossmodal reorganization involved all subdivisions of the auditory cortex (A1, AAF, PPF, PSF and ADF) and was characterized by somatosensory neurons activated by hair-receptor inputs from bilateral receptive fields primarily on the head and face. Recordings from hearing animals indicated that subthreshold somatosensory inputs were insufficient for their unmasking, by deafness, to account for the observed conversion. Furthermore, in the adult-deafened ferrets, BDA tracer injections centered on A1 revealed no retrogradely-labeled neurons outside the normal 'auditory' cortical/thalamic areas. Thus, this lack of change in anatomical connectivity suggests that the crossmodal conversion may be reflective of reorganization elsewhere in the auditory pathway, such as has been demonstrated in the brainstem of hearing impaired animals. Collectively, these data demonstrate that cortical crossmodal reorganization can occur after the period of sensory system maturation has ended.

Does color have a perceptual and/or cognitive (decisional) influence on human flavor perception?

Carmel A Levitan [1], Megumi Sugawara [2], Charles Spence [1]

[1]University of Oxford, [2]University of San Diego

Flavor constitutes a complex multisensory phenomenon, with information from many different senses combining to create the overall experience of a particular food or beverage (see Verhagen & Engelen, 2006, for a review). Over the years, literally hundreds of published studies have examined the role of color, with mixed results (e.g., Clydesdale, 1993; Hoegg & Alba, 2007; Zampini, Sanabria, Phillips, & Spence, 2008). We applied a signal detection approach in order to determine once-and-for-all whether the influence of color was primarily perceptual or decisional in nature. Participants smelled strawberry-flavored, lemon-flavored, and unflavored solutions, with the intensity of the flavoring diluted such that the solutions were presented at near-threshold concentrations. Each solution was red, yellow, or clear in color, and each combination of flavor and color was presented equiprobably. In the detection task, participants had to detect the presence of a flavoring (i.e., present vs. absent). In the discrimination task, participants indicated which flavor, if any, they perceived (strawberry, lemon, or no flavour). In the detection task, color (whether congruent or incongruent) had no effect on either the sensitivity or the criterion of participants' responses: that is, they did not make use of the color when judging whether a flavoring was present or not. Color also had no effect on the sensitivity of participants' discrimination responses. However, there was a significant interaction between color and flavoring, such that color modulated the criteria used by participants in identifying which of the two flavorings was present. Specifically, when solutions were colored red, participants were more likely to indicate that they were strawberry-flavored and less likely to indicate that they were lemon-flavored, regardless of whether the solutions were actually strawberry or lemon flavored. This result suggests that the role of color in modulating flavor perception in humans is not perceptual, but occurs at a later (decisional) stage of information processing. These results help to make sense of the conflicting results reported in previous studies in this area.

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DAY 3 - WEDNESDAY

Do effects of training on texture categorisation transfer across modalities?

Cristina Simoes-Franklin, Mark Byrne, T. Aisling Whitaker, Fiona N. Newell

Trinity College Institute of Neuroscience

Many studies have previously reported on the effects of training or expertise learning on the visual perception of highly similar objects such as faces, letters and textures (e.g. Schwartz et al, PNAS, 2002). However, very little is known about whether training effects are specific to the training modality only or whether these effects can transfer to a non-trained modality. Moreover, the neural substrates underlying the effects of training within and across modalities have previously not been investigated. We conducted two studies in which we tested the effects of perceptual training within and across modalities. Specifically, participants were trained to categorise a set of fabric samples as either 'natural' or not and we measured behavioural performance (Experiment 1) and neural activation (Experiment 2) as a consequence. The stimuli consisted of 32 different fabrics which varied gradually from natural to synthetic. During the learning session these stimuli were pseudorandomly divided into two subsets, one subset was learnt using vision and the other using touch. In Experiment 1, participants conducted a baseline block in which they were required to categorise each of the stimuli as natural or synthetic using either vision or touch. Following baseline, participants were then trained on half of the stimuli through vision only and the other half through touch only. At the end of the training session, categorisation performance was measured both in the same modality as the training modality and in the other modality. We found effects of training within modalities with a significant increase in categorisation accuracy after training. In the cross-modal conditions, training effects were found to transfer from vision to touch but not from touch to vision. In other words, whereas visual performance benefitted from tactile training of the texture stimuli, performance in the tactile modality did not benefit from visual training. In Experiment 2, functional data was acquired while participants performed a visual categorization task before and after training. Between scanning sessions the participants were trained to categorise the stimuli using either vision or touch. Preliminary analysis of the functional data comparing brain activity before and after the training session revealed differences not only in early sensory regions, but also in multisensory and higher cognitive region, particularly for the subset of stimuli learned by touch. Our results show that there are cross-modal effects during perceptual learning although these effects seem to be unidirectional and dominated by visual processing.

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DAY 3 - WEDNESDAY

Spatial and temporal factors in audiovisual interplay: An fMRI sudy

Bjoern Bonath [1], Sascha Tyll [1], Hans Jochen Heinze [1], Steven A. Hillyard [2], Toemme Noesselt[1]

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Spatial and temporal constraints determine multisensory integration (e.g. Macaluso & Driver 2005, Driver & Noesselt, 2008). Recent neuroimaging studies investigated the neural basis of audiovisual interactions in perception (e.g. Noesselt et al. 2007, Bonath & Noesselt et al. 2007) but none of these have directly compared temporal with spatial factors using fMRI. Moreover, attention to either the spatial or temporal domain may further modulate the neural underpinnings of audiovisual processing. In the present fMRI-study, we varied both spatial and temporal properties of audiovisual stimuli, while subjects performed either a temporal or spatial audiovisual discrimination task. Sounds were presented at two different spatial positions (left/right) with both simultaneous and non-simultaneous light flashes (SOA 300 ms). These sound/light combinations occurred either within the same hemifield (sound/vision left/right) or at opposite hemifields (sound left/vision right and sound right/vision left). Preliminary results revealed modulations within non-specific thalamic nuclei that were differentially modulated by task demands (attention to spatial/temporal stimulus properties). Our results are in line with recent theories on multisensory interplay in the thalamus (Schroeder & Foxe 2005) and their implications will be discussed.

Effect of vestibular information on sound source distance travelled estimation

Shuichi Sakamoto [1], Fumimasa Furune [1], Wataru Teramoto [1], Kenzo Sakurai [2], Jiro Gyoba [3],Yo-iti Suzuki [1, 4]

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From an ecological point of view, detection and localization of an approaching object as accurately as possible is an essential ability. There are two causes of approaching sound sources - a listener's movement towards a stationary sound source (LM) and a sound source's movement towards a stationary listener (SM). While both cases provide identical acoustic signals, self motion information is only available in the LM case. The aim of the present study was to compare these two conditions (LM and SM), focusing on the perceived amplitude variations in estimating distance travelled to an approaching sound source. The experimental setup consisted of a parallel swing configured for back and forth motion the sagittal plane (0.33 Hz, 20 cm max displacement), one active loudspeaker (38 cm from the listener), and one dummy loudspeaker (95 cm from the listener). The sound signal stimulus was a 1.5 s pink noise burst. The sound pressure level (SPL) of the active loudspeaker was modulated by the swing's motion to simulate the sound from the dummy loudspeaker. Participants sitting on the chair placed in the experimental position looked at the experimental setup before were blindfolded. Participants' task was to compare the perceived change of the sound pressure level caused by the motion of the participant and/or the sound source with the change imaged by participants that it should be for the experimental setup. The point of subjective equality between perceived and imagined changes was measured by using a 2AFC adaptation method. They were unaware that the dummy loudspeaker was not active. In the SM condition, both the participant and the active loudspeaker were on the floor, while the dummy loudspeaker was on the swing. In the LM condition, the participant and active loudspeaker were placed on the swing and the dummy loudspeaker was at a fixed position on the floor. Thus, all stimuli were identical in both LM and SM conditions, except for vestibular cues. In limiting the study to approaching sounds, the

sound was presented only when the participants moved forward in the LM condition or when the swing moved toward participants in the SM condition. Results showed that the perceived modulation amplitude was larger for sound source motion (SM) than the actual modulation level of the swing motion. These results suggest that self motion information from the vestibular system has an effect on the estimation of distance for approaching sound sources.

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Auditory-tactile temporal order judgments during active exploration

Ilja Frissen [1], Mounia Ziat [1], Gianni Campion [1], Vincent Hayward [2], Catherine Guastavino [1]

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We investigated if motor activity affects cross-modal perceptual temporal alignment. Fifteen participants were presented with an auditory-tactile stimulus pair and made temporal order judgments as to which one of the two came first. For the tactile stimulus we employed a high fidelity haptic device called the Pantograph; it generates forces at a moveable plate that cause tactile sensations at the fingertip that resemble exploring surfaces. It was possible to present a stimulus where the finger was stationary (Static condition), where the participant was motorically passive but was moved about by the actuators of the device (Passive), or where the participant moved actively (Active). The tactile stimulus was a brief supra-threshold force pulse orthogonal to the hand movement. The auditory stimulus was a short tone heard over headphones. The points of subjective simultaneity (with positive values indicating the auditory stimulus had to be presented before the tactile one to be perceived as simultaneous), were 9 ms (Static), -29 ms (Passive), and 12 ms (Active). One compelling interpretation of these results is that hand movements do cause a shift in temporal alignment (Passive re: Static) but efference copies from active motor commands are used to compensate (Active re: Static) for this shift.

DAY 3 - WEDNESDAY

Does sound help locate a moving visual target in a busy dynamic scene?

Daniel Rogers, Simon Dobbyn, Paul McDonald, Henry J. Rice, Carol O'Sullivan, Fiona N. Newell

Trinity College Dublin

Crossmodal influences in spatial perception have been well documented in recent years. While there has been much research into the visual effects on sound localization (e.g ventriloquist effect), relatively little is known about how sound can affect visual localization in a scene. Moreover, very little is known about how sounds can influence attentional deployment during a visual search task. Here we investigated whether sound can affect visual search performance when the target is a dynamic object embedded in a dynamic display. In Experiment 1, participants had to judge whether a visual target was present or absent in a display containing varying number of distractor items. Auditory information was either congruent, incongruent with the moving direction of the visual target, or sound was absent. In Experiment 2, participants conducted an odd-one-out task in a similar dynamic display but here sound was either congruent or incongruent with the intermittent appearance of the visual target in the display (or sound was absent). In both experiments, we found that sound significantly affected visual search performance. Furthermore, explicit instructions to either ignore or attend to the sound had no effect on the overall findings. However, in Experiment 1 in particular, sound information did not facilitate the detection of the visual target directly but seemed instead to be used to facilitate multi-object tracking in order to eliminate non-target objects during the search process. Our findings suggest that sound can affect visual search in dynamic displays and have important implications for our understanding of multisensory influences target detection in realistic scenes.

Specialization in audiovisual speech perception: a replication study

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Speech perception is audiovisual as evidenced by bimodal integration in the McGurk effect. This integration effect may be specific to speech or be applied to all stimuli in general. To investigate this, Tuomainen et al. (2005) used sine-wave speech, which naïve observers may perceive as non-speech, but hear as speech once informed of the linguistic origin of the signal. Combinations of sine-wave speech and incongruent video of the talker elicited a McGurk effect only for informed observers. This indicates that the audiovisual integration effect is specific to speech perception. However, observers might only have been motivated to look at the face when informed and audio and video thus seemed related. Since Tuomainen et al. did not control for this, the influence of motivation is unknown. The current experiment repeated the original methods while controlling eye movements. 4 observers participated in the experiment, which consisted of 3 conditions. In the non-speech condition, observers were trained and tested in their ability to categorize sine wave speech tokens in arbitrary categories. The natural speech condition was similar but used natural speech signals and observers categorized phonetic content. The speech-mode condition again used sine-wave speech stimuli but observers were informed of the speech-like nature of the stimuli and classified them according to the phonetic content. In all conditions, a white square which in some trials dimmed briefly was overlaid on the nose of the speaker. Observers were required to report this after primary target categorization. We found a significant McGurk effect only in the natural speech and speech mode conditions supporting the finding of Tuomainen et al. Performance in the secondary task was similar in all conditions indicating that observers did look near the mouth. We conclude that eye-movements did not influence the results of Tuomainen et al. and that their results thus can be taken as evidence of a speech specific mode of audiovisual integration underlying the McGurk illusion.

Reference: Tuomainen, J., Andersen, T., Tiippana, K., & Sams, M. (2005). Audio-visual speech perception is special. Cognition, 96(1), B13-B22.

Anatomical connections suitable for the direct processing of multimodal information via the rodent primary auditory cortex

Eike Budinger, Henning Scheich

Leibniz Institute for Neurobiology, Dept. Auditory Lerning and Speech

Recently it has become increasingly apparent that primary sensory cortices, like the primary auditory field AI, are not purely unimodal but also process complex information from other sensory modalities as well as non-sensory information. Here, we will review our anatomical work on the connections of the auditory cortex in a small desert rodent, the Mongolian gerbil (Meriones unguiculatus), a common animal model in auditory research. In particular we will show that AI has multiple connections with auditory, non-auditory sensory (visual, somatosensory, olfactory), multisensory, motor, "higher order" associative and neuromodulatory brain structures. These connections are suitable to mediate multimodal integration processes as observed at the level of AI and, in turn, enable AI to influence other sensory and non-sensory systems at several cortical and subcortical levels.

The issue was approached by means of the axonal transport of various sensitive neuronal tracers, mainly by the bidirectional transport of fluorescein-labeled (FD) and tetramethylrhodamine-labeled dextran (TMRD), which were simultaneously injected into different frequency regions of the gerbil's AI.

As expected, major connections of AI are with auditory structures like the other ipsilateral and contralateral auditory cortical fields and the auditory thalamus. However, approx. 18% of the inputs to AI arise from non-auditory cortical (e.g., posterior parietal cortex, perirhinal cortex) and subcortical areas (e.g., multisensory thalamic nuclei, neurotransmitter-related structures of the brainstem) as estimated by the number of retrogradely labeled cells in these brain regions.

The analysis of the topography of the FD- and TMRD-labeled cells of origin and axonal terminations, respectively, revealed that the connections between AI and the other auditory structures are usually tonotopically organized, whereas all other connections are non-tonotopic.

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The laminar pattern of corticopetal, corticocortical and corticofugal connections suggests that AI receives primarily bottom-up-like inputs from the ascending auditory pathway and conveys auditory information feedforward (bottom-up) to its cortical target areas. In turn, AI receives largely cortical feedback inputs (top-down) and projects top-down-like to its subcortical targets. However, if one considers the organization of corticocortical and thalamo-cortico-thalamic feedback loops, this plain classification of the AI connectivities becomes increasingly complex.

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Is audiotactile temporal recalibration stimulus-specific?

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Previous studies have shown that the perceptual system is able to adapt to small temporal asynchronies between signals arriving from different sensory modalities (e.g., touch and audition). However, it still remains unclear whether this adaptation is guided by a general mechanism (affecting not only the processing of the asynchronous stimuli, but also the processing of other sounds), or stimulus-specific (e.g., being restricted to the perception of sounds with a specific pitch). Participants received a 3-min exposure to brief 1500-Hz beeps and taps that could be presented either in synchrony or in asynchrony (with a constant lag of 75ms between them). After this exposure phase, the participants performed temporal order judgements (TOJs) regarding a sound and a tap presented at various stimulus onset asynchronies (SOAs). Critically, the sound could be the same (1500Hz) as in the exposure phase or a different (750Hz). Although significant shifts in the point of subjective simultaneity (PSS) were observed after the exposure to asynchrony only in the pre-exposed (and adapted) sound, the difference, in terms of PSS shift, between the pre-exposed and the non-exposed sounds was not significant. This pattern of results suggests the existence of a general (i.e., not stimulus-specific) adaptation mechanism. However, preliminary results using more distant sounds (that may be also more distantly represented in primary auditory cortex, A1; see Formisano et al., 2003) indicate the presence of pitch-specific adaptation effects. Different hypotheses regarding the level of signal processing (e.g., early vs. late) at which temporal recalibration may occur are discussed in the light of these (and previous) results.

Visual object recognition by prehension movement

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Purpose of the study: When we reach to grasp an object we shape our hand for efficient grasping well before the contact point, implying that vision is able to influence the motor command during its execution. Inferring the shape of the grasped object from observing the action may be functionally important in anticipating the consequence of the action and in interpreting the intention of other people's action. Here firstly we demonstrate the human visual system can retrieve the shape and size of the grasped object by observing only the visual kinematical information, and that these effects strongly depend on the view-point of the action respect to the observer.

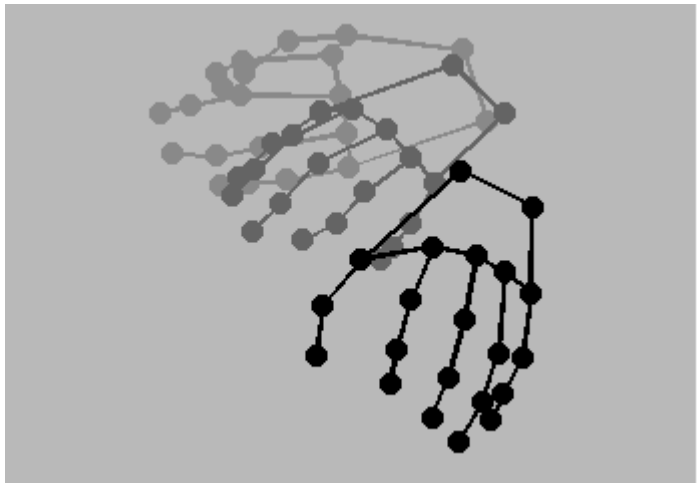
Methods: Visual stimuli were obtained by recording the right hand trajectories of 10 actors performing a reach and grasping task, using an optical motion capture system. The video sequences (≈ 1.5 s) were then transformed in dark point-line biological motion sequences (21 points) presented against a homogeneous background (see example sequence in figure). Four solid objects (cylinder, trunk, sphere and cube) were used, with 2 different volumes but matched height. Subsequently, the actors and additional 10 subjects were required to recognize the shape of the object in a 4AFC task. To control for the influence of dot positional and density cues of the final hand posture, we performed the task presenting as stimuli only the last frame of the video for 250 ms. The synthetic video and the last frame stimuli were presented in first or third person perspective (back and frontal view).

Results: The subjects discriminated well the small (cylinder and pyramids) versus the large (sphere and cube) objects both for the moving ($d'=1.64 \pm 0.62$) and the last frame stimuli ($d'=1.16 \pm 0.41$). However a positive and significant ($p<0.01$) influence of the kinematics was present only when the view was in first person perspective. The effect of the view-point was larger for the actors when recognizing their own actions.

Conclusions: These results show that the visual system can infer the shape of an object by the reaching kinematics, but only if presented in

a view-point consistent with the subject's own movement. The view-point and the agent selectivity of these results support and strengthen the direct matching hypothesis (Rizzolatti et al., 2001) that considers that observing an action engage the same motor program used to generate it. In addition they indicate that motor programs can influence directly perception.

Essential references: Rizzolatti, G., Fogassi, L. & Gallese, V. Neurophysiological mechanisms underlying the understanding and imitation of action. Nature Rev. Neurosci. 2, 661–670 (2001).



The perception of temporal regularity across modalities

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In a series of studies, Quinn, Goutcher and Watt (2007) investigated the ability to detect a temporally regular stimulus from a temporally irregular stimulus. Participants were asked to judge which of two intervals, each showing a sequence of briefly flashed lines, contained a temporally regular pattern. In the temporally regular stimulus (visual target stimulus), lines were regularly spaced in time. The other interval contained a sequence with the same overall duration, but with irregular intervals between flashed lines (visual non-target stimulus). Both stimuli were then interleaved with a further irregular sequence of flashed lines (visual distractor). Detection was possible when the visual target stimulus was presented alone, but became impossible when the visual distractor was also presented. This effect was also observed in the auditory domain: detecting a temporally regular sequence of tones was possible when they were presented without an auditory distractor, but became more difficult when the distractor was presented.

Several studies have also shown that the onset of auditory stimuli has powerful effects on the perceived occurrence of visual stimuli: a sound presented in close proximity to a visual stimulus causes the onset of the visual stimulus to appear closer in time to the sound (an effect known as temporal ventriloquism). However, this effect is not observed in reverse: the perceived onset of a tone is not pulled towards the onset of a visual stimulus suggesting a dominance of the auditory domain over the visual system. Consequently, it is possible that detecting the temporally regular visual target would be disrupted when an auditory distractor was interleaved between temporally regular flashed lines. However, the presence of a visual distractor should have no affect on the ability to detect a temporally regular auditory stimulus.

In a series of studies we investigated the ability to discriminate a temporally regular stimulus from a temporally irregular stimulus. In study 1, participants judged which of two stimuli, each showing a

sequence of flashed lines, contained a temporally regular stimulus. In the target stimulus, flashed lines were regularly spaced in time. The other pattern contained a sequence of flashes with the same overall duration, but with irregularly timed intervals between each line (non-target stimulus). Both stimuli were simultaneously presented with a temporally regular sequence of tones (auditory distractor). The second study involved the same temporal features as above, but the target and non-target stimuli were replaced by tones and the distractor sequence contained flashed lines. Detecting the auditory target stimulus was possible when it was presented with the visual distractor sequence. However, detecting the visual target stimulus was more difficult in the presence of the auditory distractor. This supports previous evidence suggesting a dominance of the auditory system over the visual system and a new version of the temporal ventriloquist effect.

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The contributions of transient and sustained responses to audio visual integration of dynamic information

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Transient and sustained responses have been shown to play distinct functional roles in auditory processing: Transient responses may subserve rapid stimulus detection, sustained responses contribute to a more detailed sound characterization. While numerous fMRI studies have reported audiovisual interactions at multiple levels of the cortical hierarchy, they were not able to dissociate transient and sustained responses. This fMRI study optimized the design to disentangle the contributions of sustained, onset and offset responses to superadditive and subadditive interactions and localize the effects within the visual and auditory processing hierarchies.

Seventeen subjects participated in this fMRI study (Siemens TimTrio 3T scanner, GE-EPI, TE = 40 ms, 38 axial slices, TR = 3.08 s). While engaged in a target detection task, they were presented with 1 s, 10 s, 20 s, 30 s blocks of (i) video clips of an expanding radial star-field, (ii) auditory pink noise or (iii) both. The velocity of the star-field and the sound amplitude were jointly modulated according to 0.1 Hz sine-wave function. The regressors of the general linear model were formed by convolving (i) delta functions encoding the onset and offset of each block and (ii) box car functions adjusted for block length with the hemodynamic response functions. Blocks of 1 s duration were modeled only as onsets. In addition, the model included targets and parametric modulators encoding the amplitude / velocity modulation. To allow for a random-effects analysis (SPM5), contrast images for each subject were entered into second level one sample t-tests. We tested for superadditive and subadditive interactions separately for onset, offset and sustained block responses. Results are reported at $p<0.05$ whole brain corrected.

Significant audiovisual interactions were observed only for the transients: For the onsets, the interactions were superadditive in the fusiform gyrus (FFG), anterior calcarine sulcus (aCaS) and the cuneus (Cun) and subadditive in the posterior superior temporal

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gyrus/sulcus (pSTS/STG) and the precuneus (PrCun). For the offsets, the interactions were subadditive in the pSTS/STG region and the anterior intraparietal sulcus (aIPS). The regional response profiles were further characterized by their general responsiveness to visual, auditory and audiovisual onsets, offsets and sustained stimulation. This dissociated three activation profiles: (i) In FFG, only the onsets elicited a strong positive response with moderate responses to offsets and sustained stimulation. Further, the onset responses were positive for visual and audiovisual stimuli and negative for auditory stimuli. (ii) In aCaS, only the offsets elicited a positive response for all sensory modalities. (iii) In the remaining regions, both onsets and offsets elicited a positive response for all sensory modalities. In conclusion, audiovisual interactions are observed primarily for transient rather than sustained stimulation. Furthermore, these AV interactions are located in regions that respond primarily to transients. In contrast, no significant interactions were observed in regions that exhibited sustained responses to extended blocks of audiovisual stimulation.

An investigation of visuohaptic integration: visual vs. haptic dominance; unimodal vs. bimodal exploration; common vs. uncommon sources

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Purpose: Perception of the external environment is dependent on input to multiple sensory modalities. Inputs from these modalities combine and interact to yield a final percept; each given a different weight under differing circumstances (Ernst & Banks, 2002). Inconsistencies in visuohaptic integration literature exist with regards to which sensory modality is given the greater weight (Ernst & Banks, 2002). The purpose of the present study was 1) to determine whether visual input influences haptic perception of line length and whether haptic input influences visual perception of line length. 2) To determine whether a produced estimate of perceived line length is more reliable with both visual and haptic exploration compared with either modality alone. 3) To determine whether produced estimates of line lengths yield greater integration of visual and haptic inputs when each emanates from a single source compared with two separate visual and haptic sources. Methods: Two experiments were conducted. The first used two separate objects (one for visual input and one for haptic input). The second used a single object which the participant both visually and haptically explored. To test whether produced responses following bimodal exploration were more reliable than produced responses after unimodal exploration two methods were used. First, participants either simultaneously explored separate visual and haptic 3-dimensional lines of equal length or used either vision or touch alone to explore a 3-dimensional line. Second, participants simultaneously explored a single 3-dimensional line using vision and touch together or using either vision or touch alone. After exploration, participants reproduced a line that either matched what they saw or what they felt. All responses were made on a touch screen tablet notebook. To test whether visual input influenced haptic perception or whether haptic input influenced visual perception the same basic method was used but a discrepancy in length between the visual and haptic stimuli was added.

Results: Produced haptic responses were nearly double in length compared with produced visual responses. Inconsistent with previous

studies, results for both experiments found that responses of bimodal exploration were not more reliable than responses of unimodal exploration. An influence of visual input on haptic perception of line length was found with separate visual and haptic objects only when participants made a visual response. An influence of visual input on haptic perception of line length and an influence of haptic input on visual perception of length was found for visual and haptic exploration of a single object regardless of the response modality.

Conclusions: 1) Produced haptic responses on a touch-screen notebook were double the length of comparable visual responses. 2) Visual input influences haptic perception of line length when visual and haptic sources are different. 3) Visual input influences haptic perception and haptic input influences visual perception when visual and haptic sources are the same. 4) Visuohaptic exploration with a common source promotes greater integration when compared with two sources, one for each modality. These findings can be applied to the development of visuohaptic technology. Realistic virtual environment and virtual training tool developers should be aware of the large discrepancy between participants' visual and haptic responses when using a touch screen notebook.

Enhancement of vocal sound detection by facial view in the monkey

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To study cortical mechanism of audio-visual (AV) integration of vocalization, we trained macaque monkey to perform the AV oddball task. Monkey initiates each trial by pulling a lever and maintaining gaze within a defined window on a monitor. In each trial, a series of "non-target" AV stimuli, composed of conspecific vocalization sounds + movie\image, are presented repetitively, interleaved with low-pass filtered or scrambled image for random duration between 600~1200 msec. Randomly after 3-6 non-targets, an AV target is presented. Targets differ from non-targets during the prior series in terms of both A and V, only V or only A, which ensures that monkey monitor both A and V. Monkey releases the lever upon detection of a target to obtain a reward. Using sound and image of simultaneous onsets, behavioral response of monkey showed multisensory facilitation; hit rate was highest for A+V change targets and lowest for A alone change targets. Reaction time (RT) was shortest for A+V change targets and longest for V alone change targets. By adding another condition using non-targets composed of only sound but still requiring bimodal monitor, it was revealed that facial view enhanced detection of A change target even at attenuated sound level at which monkey can barely detect A change when sound was presented alone.

An Investigation of Perceptual Dependencies in Audiovisual Speech Perception

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Ecological speech signals consist of both auditory and visual (lipreading) information. An important problem in cognitive psychology is determining whether the dimensions of perception, including the auditory and visual components of speech, are combined independently (e.g., Garner & Morton, 1969). To test whether the auditory and visual components are perceived independently, we implemented the statistical methodology of General Recognition Theory (GRT) (Ashby & Townsend, 1986), a multidimensional extension of signal detection theory. We carried out an identification experiment where the auditorially and visually articulated syllables of /be/ and /ge/ were combined in a 2 x 2 factorial design to yield four stimulus categories: (A_V) /be_be/, /be_ge/, /ge_be/, and /ge_ge/. The stimuli /be_ge/ and /ge_be/ elicit the classic McGurk fusions of de and bge respectively. Results obtained from model fitting indicate that the auditory and visual components of speech are perceived independently. However, marginal d's and decision criteria can differ as a function of stimulus level.

Vocalization-context dependent neural representation of faces in monkey lateral prefrontal cortex

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In daily communication, we recognize communication signals (e.g., facial expressions and vocalizations) based on preceding communication contexts. In such a context-dependent recognition of communication signals, it is important to combine multi-modal communication signals. Neurons in the lateral prefrontal cortex (LPFC) are modulated by both auditory and visual communication signals and are involved in the monitoring of prior events. Therefore, the LPFC neurons are likely to be involved in the context-dependent processing of multi-modal communication signals. To address this hypothesis, we recorded local field potential (LFP) from the LPFC of rhesus monkeys while the monkeys listened to vocalizations or viewed silent movies of monkeys vocalizing. Specifically, the stimulus-paradigm began with the presentation of 3 - 5 repetitions of the same vocalization that was followed by the presentation of the silent movie. The repeated vocalization was a coo, grunt, or scream. The movie showed the facial movements of the monkey that were elicited by the vocalization. Importantly, all of the vocalization-movie stimuli came from the same monkey, eliminating any individual-based factors. The vocalization and the movie were either congruent (e.g., the vocalization was a coo and the movie showed a monkey cooing) or incongruent (e.g., the vocalization was a coo and the movie showed a monkey grunting). We analyzed 96 sites that showed a significant increasing in LFP (frequency range: 4 - 100 Hz) during the period of time that the movie was presented in the environment (movie-stimulus period). We found that the peak power and the latency to peak power of the LFP (4 - 50 Hz) during presentation of the vocalization (vocalization period) was modulated by both the type of vocalization and the number of preceding vocalizations. Also, the LFP (4 - 100 Hz) during the movie-stimulus period was modulated by both the type of vocalization and the number of vocalizations that preceded the presentation of the movie. Data to

date suggest, however, that this modulation was not strictly dependent on whether or not the vocalization and face were congruent. Overall, these findings suggest that a neural system in the LPFC processes faces in a vocalization-context dependent manner. Such a mechanism in the LPFC may contribute to recognition of communication signals in a context-dependent format.

Investigating viable criteria for assessing neuronal convergence with BOLD fMRI

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The majority of our understanding of the ability of the human nervous system to merge multiple sensory modalities originates from single-unit studies of non-human animals. These groundbreaking neurophysiological studies established many principles for understanding multisensory processing at the level of single neurons, including the criterion with which experimenters assess integration of multiple senses. It is tempting to consider that neuroimaging measurements, like blood oxygenation-level dependent (BOLD) activation measured with fMRI, are directly comparable with findings from single-unit recordings. Although several studies have established clear links between BOLD activation and neural activity there remains a fundamental difference between BOLD activation and single-unit activity: BOLD activation is measured from the vasculature supplying a heterogeneous population of neurons, whereas singe-unit measures are taken from individual neurons. The ramifications of this difference are not inconsequential, because the principles of multisensory phenomena established using single-unit recording may not apply to population-based neuroimaging data The established principles must be tested theoretically and empirically, and where they fail they must be replaced with new principles that are specific to the new technique.

Using a modeled BOLD response based upon known populations of neurons within the superior colliculus, including both unisensory and multisensory neurons, we have assessed three criteria commonly used in BOLD fMRI to identify purported multisensory brain regions: the maximum criterion (AV > Max(A,V)), the additive criterion (AV > Sum(A,V)), and the mean criterion (AV > Mean(A,V)). We show that the linear, time-variant properties of the BOLD response suggest that a single region consisting of only unisensory neurons would produce a BOLD response that exceeds both the maximum and mean criterion, and as such, the presence of unisensory neurons within a multisensory brain region invalidates the usage of both the criteria. Our models

show the additive criterion to fall short of the ability to assess neuronal convergence on two accounts. Single-unit studies have shown that only a minority of multisensory-enhancing cells respond in a superadditive fashion, but to exceed the additive criterion the mean response of all multisensory neurons within a given region must be superadditive. Also, the additive criterion is influenced by the experimenter's choice of baseline. The lower the unisensory response is relative to baseline, the more liberal the additive criterion becomes.

Here, we propose a criterion to assess neuronal integration of senses specifically designed to be both theoretically and empirically viable when used with the BOLD signal. By varying an added stimulus factor such as stimulus saliency, one can measure the change in BOLD activation in unisensory and multisensory conditions. Inequalities between the relative differences in the multisensory condition and the sum of the relative differences in the unisensory conditions ($\Delta AV \neq \text{Sum}(\Delta A, \Delta V)$) indicates an interaction between the two sensory streams in a way that is not sensitive to experimenter-chosen baseline and accounts for the population-based aspect of the BOLD signal. Additionally, such a measure provides insights into what stimulus aspects are being integrated, as opposed to merely labeling a particular brain region as a site of integration.

Vestibular facilitation of optic flow parsing

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Introduction: Self-motion relative to the stationary environment produces a globally consistent pattern of visual motion on the retina known as optic flow. Local motion signals inconsistent with the global flow are generated by objects moving relative to the scene. The nervous system must therefore parse retinal image motion to estimate object motion and self-motion separately. Here we investigate whether simultaneous vestibular self-motion facilitates this parsing process.

Methods: Experiments were conducted using a motion platform and attached visual display. There were two conditions, Visual-only and Combined (Visual/Vestibular), and trials for these conditions were interleaved. The visual stimulus consisted of a 3D starfield and a spherical object located to the left of the fixation point; both the starfield and the object were composed of randomly placed, limited-lifetime, frontoparallel triangles rendered in stereo. On each trial, the visual stimulus (and motion platform on Combined trials) simulated an earth-horizontal translation of the subject relative to the world and simultaneous vertical displacement of the spherical object upwards or downwards. Subjects were asked to discriminate the direction of object movement. Object displacement (and velocity) was varied from trial to trial according to a staircase procedure and psychometric functions (cumulative Gaussian) were fit to estimate discrimination thresholds. This procedure was repeated for forward, lateral (rightward), and two intermediate heading angles.

Results & Conclusions: Repeated measures ANOVA with condition (Visual-only or Combined) and heading direction as factors revealed a significant effect of condition ($p=0.03$) and heading direction ($p<0.001$) and a significant interaction ($p=0.02$). Thresholds were reduced in the Combined condition relative to the Visual-only; optic flow parsing was facilitated by congruent vestibular stimulation. Thresholds were lowest for lateral heading (laminar flow) and highest for forward movement (radial flow), probably because of the geometry of the optic flow pattern. Finally, vestibular facilitation was greatest for lateral heading but negligible for forward movement.

A Comparison of Spatial Receptive Field Architecture of Multisensory Neurons in Subcortex and Cortex

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Our environment is comprised of numerous dynamic sensory cues that are constantly changing in complex ways across the dimensions of both space and time. The role of the nervous system is to resolve the inherent ambiguities that result from these competing stimulus complexes in order to create veridical percepts. To accomplish this task, the brain has to correctly identify whether multiple sensory energies belong to a single event or several discrete events. Specific brain structures, including the midbrain superior colliculus (SC) and the cortex of the anterior ectosylvan sulcus (AES), have evolved to integrate multiple unisensory signals in order to resolve these uncertainties (i.e., multisensory integration). Prior work has established that the spatial location of stimuli is an important determinant of multisensory interactions. More recently, spatial receptive field (SRF) analyses of multisensory AES neurons has revealed strikingly heterogeneous receptive field architectures under both unisensory and multisensory conditions. The current study sought to extend this line of investigation to the superior colliculus (SC), and compare SRF architecture in these two multisensory structures. Multisensory SC neurons were isolated via standard extracellular single unit recording methods. Unisensory and multisensory SRFs were derived and compared to one another, to several predictive models, and between brain structures. In general, the unisensory and multisensory SRFs for individual SC neurons had a similar spatial organization (although gains could be dramatically different). In contrast, AES SRFs are frequently markedly different between both the unisensory and multisensory conditions. In addition, whereas cortical (i.e., AES) multisensory neurons are typically characterized by a single area of maximal response (i.e., hot spot), SC multisensory neurons ranged from having a similar singular architecture to having multiple hot spots. Despite these differences in SRF organization, the spatial heterogeneity of SRFs in both AES and SC dictated the final product of the resultant multisensory interactions, in that response efficacy was inversely related to multisensory interactive magnitude. These results suggest a universal multisensory coding concept in which receptive field architecture is a key factor, and which highlights the dynamic interplay between space and effectiveness in shaping the final neural product.

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A Visual or Tactile Signal Can Make the Auditory System More Efficient but Not Less Noisy

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Multisensory stimuli improve auditory speech detection thresholds, particularly, under noisy background conditions. In a previous study [1], an auditory stimulus "ba" was detected at lower signal-to-noise ratios (SNR), when it was presented simultaneously with a video of the talker's face, or with one of several other non-speech visual stimuli, including, a static square, a dynamic square, and a dynamic circle. We hypothesized that this effect could be due to a change in the sensory noise under multisensory conditions, or a change in perceptual efficiency. We implemented an external noise paradigm [2] in order to model two separate, independent sources of potential multisensory threshold improvement, a sensory reduction in intrinsic noise and/or an increase in sampling efficiency. Intrinsic noise is the inherent noise in the sensory system and is theoretically stimulus-invariant. Efficiency is a measure of stimulus information utilization. Efficiency is considered to be a measure of the tuning of a perceptual system to the specific task-relevant stimulus attributes, such as the stimulus onset time or spatial properties.

In Experiment 1, participants were tested on detection of the spoken "ba" from [1] with the external noise paradigm [2] at four fixed noise levels (i.e., 20, 40 and 60dB SPL white noise, and no-noise). An adaptive staircase method was used in which the acoustic signal level was varied and the noise level was fixed to obtain the 79.4% correct detection thresholds for a 2IFC task. Four conditions were tested, audio only (AO), audio with a vibrotactile pulse-train stimulus (AT), audio with a rectangular visual stimulus (AVR), and audio with visual speech (AVS). The statistically reliable relationship among speech detection thresholds across the noise levels was AO > (AT ≈ AVR) > AVS. The AVS efficiencies were higher than the AO efficiencies. The AT and AVR efficiencies were higher than the AO efficiencies, but with individual variation in the relative order of effectiveness of the two stimuli. Intrinsic noise was near zero. Thus, for normal-hearing participants, threshold improvement with multisensory stimuli is mainly due to an improvement in efficiency, with no significant effect on intrinsic sensory noise across conditions.

When the masking noise is much higher than the intrinsic sensory noise, d' = sqrt (efficiency * SignalEnergy / NoiseEnergy), which allows a direct estimate of sampling efficiency. In Experiment 2, the method of constants was used to obtain d', and two new multimodal conditions were introduced, AVR + tactile (AVRT) and AVS + tactile (AVST). A preliminary experiment fixed the signal level at 55dB SPL and varied the noise level adaptively to determine a range of SNRs suitable for constant stimuli presentation. Detection was then tested at -13,-14, and -15dB SNR. AT, AVRT, AVS, and AVST all resulted in higher d' than did the AO condition, and this elevation in d' was indistinguishable amongst conditions. This result replicates our previous finding that a concurrent non-informative stimulus without speech-related qualities can be as effective as a natural speech stimulus in its threshold enhancement effect. Overall, the results support the view that auditory speech detection in noise is enhanced whenever a visual and/or tactile stimulus affords information to improve sampling of the auditory stimulus, and that internal sensory noise is unaffected by those visual and/or tactile stimuli.

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Auditory influences on attending to and processing low-level visual stimuli early in development

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Most previous studies of cross-modal interactions in infants have focused on the integration of higher-level visual and auditory stimuli, such as faces and voices, or on the spatial and/or temporal constraints on integrating low-level sensory stimuli to create a unified cross-modal percept. Here we investigate whether auditory cues can alter an infant's ability to detect and attend to near-threshold visual stimuli.

We used forced choice-preferential looking (FPL), to determine contrast detection thresholds for a visual stimulus (a square subtending 11x11 degrees of visual angle, centered 15 degrees to the left or right of monitor center). The visual stimulus fluctuated in luminance at 1 Hz. The auditory stimulus was a white noise fluctuating in loudness at 1Hz, presented binaurally to be perceived as coming from straight ahead. The same visual stimulus was presented under four different auditory conditions: (1) In-Phase (IP): The visual stimulus fluctuated in-phase with an auditory stimulus (2) Out-of-Phase (OP): The visual stimulus fluctuated out-of-phase with the auditory stimulus, or (3) No Sound (NS): The visual stimulus was presented without a concurrent auditory stimulus. On any given trial the visual stimulus was presented at one of five contrasts (3-100%), which were randomized across trials. Contrast threshold was defined as the contrast yielding 75% correct performance in the FPL task (where correct was defined as looking to the side of the monitor containing the visual stimulus). For each subject, visual contrast thresholds were obtained for two of the three conditions (IP, OP, NS). If synchronized auditory information enhances visual detection, we expect lower contrast thresholds for the IP versus the OP or NS condition. Conversely, if synchronized auditory information hinders visual detection, we expect higher contrast thresholds for the IP condition.

We found that visual thresholds tended to be higher for the IP versus the OP condition in both 3 and 6-month old infants. These effects were due to lower thresholds in the OP condition relative to the control, NS, condition and a trend towards higher thresholds in the IP condition relative to control. Thus, anti-correlated auditory information can enhance visual detectability, while correlated auditory information can diminish visual detectability, under certain conditions. Furthermore, these results further suggest that, for the low-level sensory stimuli used here, infants may be limited in their ability to attend to information in more than one sensory modality at a given time.

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I'll be your mirror: Visuo-tactile stimulation modulates the representation of one's own face

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Background: Our body is at the basis of how we perceive the world but also of how we perceive ourselves, and thus, it is intimately related to the sense of self. Though ample body of research has focused on self-perception and self-recognition processes, the underlying mechanisms are still unclear. On one hand, face-recognition studies suggest that visual recognition of stored visual features and configurations inform self-face recognition. On the other hand, research on body ownership suggests that self-body representation and recognition largely result from the integration of current multisensory information. The interaction between these two views was assessed in a recent study (Tsakiris, 2008) showing that self-face representation can be modulated by concurrent visuo-tactile stimulation. In two follow-up experiments we further investigate the role of current multisensory stimulation on explicit and implicit tasks of self-face recognition and on the participant's subjective experience.

Methods: Participants were presented with a movie of someone else's face (an unknown control face) being touched on the face, whilst the participant's face was similarly touched either in synchrony or asynchrony. Immediately before and after this induction period, participants performed a task to quantify the effects that visuo-tactile stimulation had in the participants' perception of their own face. In Experiment 1 we obtained an explicit measure of bias in "self" versus "other" judgments for morphed faces, while Experiment 2 used an implicit measure of sensitivity to dissimilarity between a picture depicting a 50% morphed face and another picture with a varying degree of face morphing. In addition, introspective ratings for perceptual experiences during both synchronous and asynchronous visuo-tactile stimulation conditions were collected.

Results: Experiment 1 shows that changes on explicit self-face recognition have an egopetal or inwards direction of change: the "other's face" becomes more part of "me", than "my face" becomes part of the "other". This effect can not be accounted solely by self-familiarity since asynchronous visuo-tactile stimulation did not produce the same bias. This asymmetrical effect was also observed in the implicit task of Experiment 2, where the sensitivity to dissimilarity of pictures with various degrees of face morphing decreased after synchronous visuo-tactile stimulation only. Analysis of introspective evidence reveals significant changes in the perception of self (e.g. "It seemed like I was looking at my own reflection in a mirror rather than at the other's face") and other (e.g. "The other's face began to resemble my own face") as a result of synchronous visuo-tactile stimulation. Conclusions: The present results show that participant's partly incorporated the other person's face in their own face representation, suggesting that current multisensory stimulation may indeed alter the internal representation of one's own face, and the perception of other people as being more similar to us.

Reference: Tsakiris, M. (2008). Looking for Myself: Current Multisensory Input Alters Self-Face Recognition. PLoS ONE, 3(12), e4040.

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Vestibular perception is slow

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In contrast to other senses, the latency of vestibular sensation has not been well investigated. We therefore measured the perceived timing of vestibular sensation relative to visual, tactile and auditory stimuli. Three types of vestibular stimulation were used: galvanic vestibular stimulation (GVS), passive head movements (HMp) and active head movements (HMa). Temporal order (TOJ) and simultaneity judgments (SJ) and reaction times (RTs) were made relative to full-field flashes, 50ms bursts of white noise, or of vibration of the finger tip. TOJs and SJs between vestibular and other sensory stimuli required the vestibular stimulus to occur ~160ms before other sensory stimuli for GVS (Fig. 1a), ~50ms before for HMp (Fig. 1b) and ~80ms before for HMa (Fig. 1c) in order for the pairs to be perceived as simultaneous. RTs to GVS-induced illusory head movement (438ms) were significantly longer than RTs to touch (245ms), light (220ms) or sound (197ms) (Fig. 1d) but not by enough to predict the TOJ and SJ results (Fig. 1e). The largely uncompensated lag in vestibular sensation probably reflects the fact that the vestibular system rarely works alone. The short latency eye and balance motor responses traditionally associated with the vestibular system are divorced from the perceptual correlates.

Decomposition of audiovisual interactions in event-related fields using independent component analysis

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Introduction: Selective attention is fundamental to the localization of sensory information from different modalities. Several studies have reported multimodal interactions evident in amplitude and/or latency differences of event-related potentials (ERPs) (Eimer & Schröger, 1997; Molholm et al., 2002; Giard & Peronnet, 1999) and event-related fields (ERFs) (Shams et al., 2005). By using high-density recordings, the spatial topography of these event-related brain processes may be resolved. However, a particular waveform may be generated by multiple spatially-discrete neural sources. Thus, regional averaging techniques, commonly applied to reduce the dimensionality of high-density recordings, may not fully capture important aspects of the event-related dynamics derived from a large number of signals. Independent component analysis (ICA) is an ideal tool to track both the temporal and spatial dynamics of electroencephalographic (EEG) and magnetoencephalographic (MEG) data during different sensory, motor, and attention-related processes.

Purpose and Approach: The purpose of this study was two fold. First, we examined interactions between visual and auditory attention on behavioral performance and cortical activation patterns during spatial localization using traditional regional averaging ERF techniques. Second, we decomposed the event-related fields from the whole scalp using ICA infomax (Makeig et al., 1997) to confirm and isolate neural processes involved in the low-level sensory interactions, movement-related activity, and spatial attention.

Methods: Whole-head MEG was recorded from 10 right-handed participants during the performance of an audio-visual cued attention paradigm. During the baseline conditions, a visual stimulus (8.7° to the right or left of a central fixation) or an auditory stimulus (monaural to the right or left ear) was presented for 50ms. Participants were instructed to respond quickly and accurately to the location of target

(left or right). During the cued conditions, visual or auditory cues were presented 750ms prior to the target stimuli. For 80% of the trials, the cue was presented in a congruent spatial location as the target. The spatial location (left versus right), sensory modality (auditory versus visual), and condition (baseline versus cued) were used as factors to examine differences in: 1) the behavioral responses (reaction time and accuracy), and 2) the ERFs.

Results: Preliminary results indicate that spatially-congruent auditory cues facilitated the reaction time and accuracy to targets in either modality, whereas visual cues impeded behavioral responses to auditory targets regardless of the spatial congruency of the cue. Consistent with these results, auditory cues modulated the MEG ERFs (specifically the M100 and M200 components) in the primary unisensory areas (particularly over the auditory cortex) during target presentation. ICA analysis confirms an interaction of auditory cues on responses to visual stimuli, as well as decomposed downstream motor processes and attention-related components. These findings suggest that low-level multisensory interactions may modulate downstream processing improving the quality of the behavioral responses (accuracy and speed).

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Completion of a visual motion representation by auditory information

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Humans perceive or recognize a moving visual object even if the object is temporarily invisible by an occluder. This fact suggests that the representation of the visual object is maintained by amodal completion mechanisms in each sensory modality and, likely (however, not well investigated so far), by information from the other modalities such as audition. In the present study, we investigated whether and how auditory information helps to maintain a visual motion representation. Kanai et al. (2007) showed that a transient gap of a smoothly moving visual stimulus could be easily detected if it occurred soon after the motion onset (< 200 ms), but less if it occurred later than 300 ms. This finding suggests that the motion representation evolves gradually with the increment of visual motion inputs, and that once the motion representation is fully constructed, the gap can be filled in. Thus, we used the detection performance of a transient gap within a visual motion sequence as an index of the completion of a motion representation. In our display, a sequence of visual stimuli in spatiotemporally adjacent positions was presented as smooth motion sequence in the horizontal direction for 800 ms. An occluder (173 ms) was set in the middle of the motion path. A transient gap (13.3 ms) was introduced into the motion sequence. The participants' task was to detect the gap. Two independent variables were introduced: motion path (behind or in front of the occluder) and presentation of auditory motion which was simulated by dynamically changing the interaural level difference (ILD). When the visual stimulus traveled in front of the occluder, the previous finding was replicated – higher sensitivity to gaps soon after the motion onset and lower sensitivity to gaps later than 300 ms – irrespective of the presentation of auditory information. When the visual stimulus traveled behind the occluder (i.e., temporarily invisible) without auditory information, the detection performance was kept higher for the gaps later than 300 ms (i.e.,

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after the occluder), indicating that the occluder disrupted or reset the formation of the motion representation. In contrast, when the motion sequence was accompanied with auditory information, the detection was impaired regardless of the occluder. These findings suggest that auditory information contributes to the maintenance of a visual motion representation when a moving visual object is temporarily invisible.

Pay attention, the message is coming up!

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The brain integrates information from both vision (lips movements) and audition (vocal sounds) during speech perception. Alsius et al. (2005) demonstrated that audiovisual speech integration falters under conditions of high perceptual load. Here, we investigated whether the temporal orienting of attention modulates the integration of audiovisual speech signals by measuring the prevalence of the McGurk effect under conditions of low perceptual load. Videoclips of a female speaker pronouncing different syllables (some of them containing McGurk-like combinations) were presented. Participants had to report what they perceived. Prior to the appearance of each videoclip participants were presented with an attentional cue indicating whether the speaker would appear soon (400) or late (1400) with a probability of 75%. The results showed a larger McGurk effect (arguably, greater audiovisual integration) when the stimuli appeared at the cued moment with respect to the uncued moment. Theses results clearly demonstrate that audiovisual speech integration depends on the deployment of attention even under conditions of low perceptual load.

Integration of Cued Speech with residual hearing

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Cued Speech is a manual system that was designed to disambiguate visible speech information and thus afford full speech information to a person with a hearing loss. Cued Speech has been shown to contribute significantly to the acquisition of language and reading skills in deaf children through early and extensive exposure to it. In the present study, the potential use of Cued Speech as a multisensory tool for auditory rehabitation for adult cochlear implant recipients was examined through a simulation of residual hearing using vocoded speech. A specific question was whether Cued Speech can be integrated with adult cochlear implant recipients' residual hearing and lipreading. Towards this end, a computer-based Cued Speech English synthesis system was developed that used concatenative methods to synthesize visible hand cues. The synthesized visible hand cues were overlaid onto naturally recorded visible speech. Speech materials consisted of 260 consonant-vowel-consonant-vowel-consonant nonsense words. This set of words was developed through a Monte Carlo method so that they had similar characteristics to real words in English. These words were realized with audiovisual speech and audiovisual speech plus synthesized visible hand cues. Twelve adult participants with normal hearing were trained on Cued Speech using 120 words with visible speech plus synthesized/natural visible hand cues. After about 10 to 15 hours of training, a first test examined whether these participants perceptually process both visible speech and visible hand cues. A set of 120 nonsense words, different from those used in the training, was presented in an open-set identification task, for which participants entered what was said using a computer keyboard. Within the test words, there were 30 words with visible speech only and 30 words with visible speech plus synthesized visible hand cues. Results show that phonemes correct scores with visible speech plus synthesized visible hand cues were higher than those with the visible speech only stimuli. This indicates that participants can learn Cued Speech and integrate visible hand cues with their lipreading. To simulate the usage of Cued Speech by adults with cochlear implants, these participants with normal hearing also performed an open-set identification task with vocoded speech. A two-channel vocoding was used to simulate a situation that adults with cochlear implants receive very limited auditory information from their implants. Specifically, the speech signals were band-pass filtered into two frequency bands, the extracted temporal envelope in each frequency band was used to modulate a sinewave carrier, and the modulated bands were then summed. The same set of 120 test words was used after randomization. Within the test words, there were 30 words with vocoded speech only, 30 words with vocoded speech plus visible speech, and 30 words with vocoded speech plus visible speech plus synthesized visible hand cues. Results show that synthesized visible hand cues improved vocoded audiovisual speech perception. An additional test was performed in the end to demonstrate that the improvement of vocoded audiovisual speech perception with visible hand cues was not solely from visible speech plus synthesized visible hand cues or from vocoded speech plus synthesized visible hand cues, but instead, was from vocoded speech plus visible speech plus synthesized visible hand cues. Furthermore, correlation analyses of confusion matrices indicate that the perception of vocoded speech only, visible speech only, and visible hand cues only accounted for 73%, 63%, and 51% of the variance in the perception of vocoded speech plus visible speech plus visible hand cues, respectively. In summary, the present study demonstrated that after training on Cued Speech, adults with normal hearing can integrate their perception of visible hand cues with their perception of visible speech and simulated "residual hearing," achieving three-modality integration. An implication is that Cued Speech can provide adults with cochlear implants an integrative but not distracting source of information and thus can be a potential multisensory tool for auditory rehabitation. [Work supported by an NIH/NIDCD Grant R03DC007976.]

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Investigating the Interplay of Time & Semantics during Multimodal Integration

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Real world events often give rise to information across multiple perceptual modalities. Tapping a pencil provides correlated auditory and visual information to the senses. How are such events neurally represented? Prior behavioral and neural research on multimodal integration has identified the critical role of spatial, temporal, and semantic congruency between modalities as factors guiding the integration between modalities (Meredith & Stein, 1993; Doehrmann & Naumer, 2008). That is, multimodal information arising from a common physical cause shares a common temporal structure, the same spatial location, and has semantic associations based on context and prior experience. We investigate how two of these factors, temporal and semantic congruence, interact during multimodal integration. We studied these factors in two separate experiments, one employing event-related fMRI and one employing EEG. In both experiments, participants viewed and/or heard 2-second real-world environmental events that contained discrete impacts, such as splashing water or snapping twigs. These events were then edited to create 4 multimodal conditions in a 2x2 factorial design that crossed semantic congruence and temporal congruence.

Condition Semantically Congruent? Temporally Congruent?

1 SC:Yes TC:Yes (original movie)

2 SC:Yes TC:No

3 SC:No TC:Yes

4 SC:No TC:No

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The fMRI study identified several brain regions showing a main effect of semantic congruence (i.e., Conditions 1 & 2 vs. Conditions 3 & 4) in the frontal cortex, including the left inferior frontal gyrus. The main effect of temporal congruence (Conditions 1 & 3 vs. Conditions 2 & 4) revealed a somewhat larger network of regions in the middle frontal, posterior temporal, and inferior occipital cortices. In addition, the EEG data provides more fine-grained information about the temporal dynamics of these effects – identifying when temporal and semantic congruency influence processing. The EEG data will further be used to guide a functional connectivity analysis of the fMRI data, providing a more informed account of how different brain regions interact during the processing of multimodal stimuli.

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Distortion of visual and auditory duration in short term memory

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Many studies have investigated inter- and intra-modal processes of time perception by employing temporal two-alternative forced choice (tTAFC) paradigm. A tTAFC paradigm generally assumes no bias in time perception while the temporal property of interest is retained in short term memory. However, how temporal information is retained in short term memory is not well understood. We examined how duration information of visual and auditory event is retained in short term memory and found a systematic memory distortion for visual, but not auditory events.

In a trial, observers compared the duration of first stimulus with that of second stimulus. In Experiment 1, the stimuli were white circles on a gray background. The first stimulus was presented for 765, 882, 1000, or 1118 ms, and the second stimuli was presented for 235, 118, 59, or 0 ms longer or shorter than the first stimulus. The blank retention interval between the stimuli was varied between 0.5 to 5 s. From derived psychometric functions, we estimated point of subjective equity (PSE) and just noticeable difference (JND) for each interval condition. The retention interval did not change the JND, but significantly affected PSE: the first visual stimulus was perceived shorter than second one (about 50 – 70 ms) when the interval was longer than 3 s. No correlation was found between JND and PSE, suggesting that the effect was not due to decision bias in unconfident trials. In Experiment 2, the visual stimuli were substituted by auditory tones. No effect of retention interval on PSE was observed. In Experiment 3, the period of visual stimuli in Experiment 1 was replaced by a blank interval between visual flashes (85 ms). Results showed that there was no effect of retention interval on PSE for visual interval judgment, but JND increased (i.e., temporal resolution became lower) as the retention interval increased.

These results suggested that retention process for visual duration information may differ from that for auditory duration. In addition, the retention interval for visual memory had differential influences on duration and interval judgment, suggesting that the memory distortion may be a manifestation of specific process for visual duration retention.

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Brain topography and the binding problem at the multisensory level in humans: new insights gained by using fMRI spectral analysis

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Events in the world are mediated to our brain through multiple sensory inputs, each describe a distinct form of energy. These inputs are processed separately to some degree, according to the division of labor principle (Zeki, Nature 1978), and then have to be integrated to create a unified representation of an event. How this is done is very poorly understood, especially in humans. We applied spectral analysis and simultaneous auditory and visual stimuli, each with a different number of repetitions, with on and off convergence and synchronization between them. We managed to separate the unisesnory events, and reveal known cochleotopic and retinotopic organization; maps within the auditory-responsive region show multiple iso-frequency bands, in addition to the mirror symmetric cochleotopic maps in the auditory core area on the lower bank of the lateral sulcus, and the maps within the visual-responsive region show the known fovea to periphery gradient parallel to calcarine sulcus. Furthermore, a gradual change from primary to multisensory areas could be traced, by using relative contribution index. Some multisensory cortical areas showed high correlation to both auditory and visual stimuli, amongst them are posterior superior temporal sulcus (STS) and the areas immediately surrounding Heschel's Gyrus. These multisensory areas might demonstrate both cochleotopic and eccentricity maps. Another multisensory network was detected, showing activation at lower frequencies, associated with binding of multisensory input during periods of audio-visual synchronization. These results provide a powerful new method both to use neuroimaging more efficiently (for instance to perform cochleotopy and retinotopy in the same scan) and more importantly to be used to study multisensory interaction and the binding problem.

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A visuo-haptic object-related fMR-adaptation: a new approach to studying multisensory interactions

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Neuroimaging techniques have provided ample evidence for multisensory integration in humans. However, it is not clear whether this integration occurs at the neuronal level or whether it reflects a real convergence without such integration. To examine this issue as regards visuo-tactile object integration we used the repetition suppression effect, also known as the fMRI-based adaptation paradigm (fMR-A). Under some assumptions fMR-A can tag specific neuronal populations within an area and investigate their characteristics. This technique has been used extensively in unisensory studies. Here we applied it for the first time to study multisensory integration and identified a network of occipital (Lotv and Calcarine), Parietal (aIPS), and Prefrontal (Precentral sulcus and the Insula) areas all showing a clear crossmodal object related fMR-A. These results provide a crucial first insight into the neuronal basis of visuo-haptic integration of objects in humans and highlight the power of using fMR-A to study multisensory integration using non-invasinve neuroimaging techniques.

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Inverse effectiveness in the left but not right lateral occipital cortex during visuo-haptic object categorization

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Purpose of the Study: There are many studies that have investigated the neural substrates involved in visuo-haptic object recognition, but few, if any, have assessed whether or not the cortical sites implicated in visuo-haptic object recognition show evidence of neuronal convergence. In a previous study, using an additive-factors design, we found evidence for neuronal convergence in three distinct object-selective brain regions in the left hemisphere. In that study, participants touched objects, viewed pictures of objects, and simultaneously touched objects while viewing pictures. Although the pictures were of the same objects that they were touching, the procedure led to incongruencies in spatial location and temporal synchrony of visual and haptic object exploration. The present study used the same additive-factors design, but with a more "ecological" procedure, where participants were able to view their hand touching the objects through a mirror. The additive-factor in this study was 'difficulty' instead of 'stimulus saliency', which was varied by changing the similarity of objects in a two-alternative forced-choice (2AFC) task.

Methods: Fourteen volunteers (seven females, age 20-34, right-handed) participated. All participants were familiarized with the task before imaging. All objects were tangible and made of ABS plastic. Object-selective brain regions were functionally localized in individual participants by a contrast of visual objects with visual textures in conjunction with a contrast of haptic objects with haptic textures. In the second phase of the study, participants were presented with objects, and asked to make a 2AFC for whether the object was more square or more round. Difficulty of the task was manipulated across runs by changing the similarity of the curvature of the two objects. Participants viewed the objects without touching (V), touched the objects without opening their eyes (H), or viewed their hand touching the object (VH).

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Results: Bi-modal object-selective regions-of-interest (ROI) were more reliably found in the left hemisphere (LH; N=11) than right (RH; N=8). Difficulty level had a significant effect on BOLD activation in the left lateral occipital tactile-visual area (LOtv) with the uni-sensory conditions (V & H). As difficulty increased, activation decreased (Figure 1). This effect was weaker with the multisensory visuo-haptic condition (VH). To assess neuronal convergence in left LOtv with the additive-factors design, we calculated BOLD differences between high-difficulty and low-difficulty conditions (Figure 2). ΔVH was significantly less than the sum of ΔV and ΔH, suggesting that visual and haptic sensory channels are integrated in left LOtv. Multisensory gain in left LOtv increased with decreasing effectiveness, an effect called inverse effectiveness. The same ROI analysis in right LOtv showed no evidence for neuronal convergence (Figure 2). A whole-brain SPM analysis found evidence of inverse effectiveness in other regions, including the intraparietal sulcus, parietal operculum, and fusiform gyrus, all in the LH.

Conclusions: Using this more "ecological" procedure, activation during visuo-haptic object categorization showed a pattern of inverse effectiveness, which is consistent with established principles of multisensory integration. Although both left and right LOtv areas were recruited for the visuo-haptic object recognition, only left LOtv showed evidence of multisensory integration.

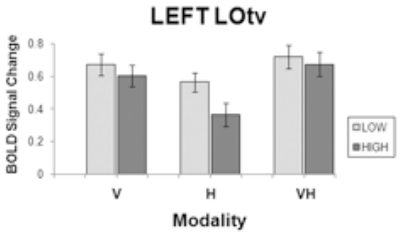

Figure 1. BOLD signal change in left LOtv as a function of sensory modality and difficulty level of the task

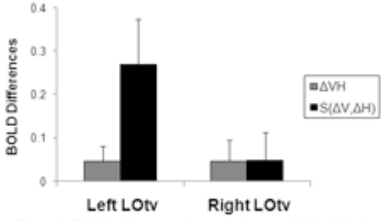

Figure 2. BOLD differences between low- and high-difficulty conditions in left and right LOtv. Light gray bars represent ΔVH and dark gray bars represent the sum of ΔV and ΔH.

Does a task-irrelevant sound modulate the spread of visual attention differently in lateral versus central visual attention?

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A task-irrelevant sound occurring synchronously with a visual stimulus arising from a different location can lead to increased activity in both the visual and auditory cortices when the visual stimulus is attended vs. unattended, reflecting the object-related spreading of visual attention across both space and modality (Busse et al., PNAS, 2005). Here, we asked if and how ERP brain-activity patterns for this multisensory 'spreading of attention' would be modulated when visual attention is focused on a lateral vs. a central location, and how this would vary as a function of whether there was object-related conflict between the relevant visual and irrelevant auditory inputs.

In two separate EEG experiments, subjects' attention was either focused on a central or to a lateral position while discriminating the visual component of congruent vs. incongruent letter-sound pairs. In the lateral task, subjects attended to one of two concurrent streams of visual letters presented to the left and right fields. In the central task, only a central letter stream was presented and was always fully attended. In both tasks, on some trials, a task-irrelevant letter sound was presented centrally. Using appropriate subtractions, we extracted the auditory ERPs to the task-irrelevant auditory stimulus for the congruent and incongruent combinations in the attended central and lateral conditions, as well as in the unattended lateral condition.

Reaction times (RT) to the visual stimuli were slower overall for the lateral task, but the incongruency RT effects were significantly larger, likely indicating increased influence of the task-irrelevant sound with increased task difficulty. In each task, for trials in which the visual stimulus was attended, the extracted auditory ERP showed a negative-polarity, frontally distributed, incongruency effect starting at ~200 ms, consistent with the synchronous incongruent letter sound acting as a distracter that captures attention. Beyond ~300ms, the lateral task showed an absolute increase in the extracted auditory-ERP negativity in the congruent condition as well, although still less than in the incongruent, thus resulting in an overall smaller difference of attended incongruent vs. attended congruent combinations at these longer latencies. The auditory combination with an unattended visual stimulus provided an additional control in the lateral task, showing that these effects occurred mainly when the visual stimuli were attended. One exception was a small negativity at ~500ms for congruent vs. pure visual in the lateral unattended condition, perhaps reflecting some automaticity of speech processing. In summary, the results suggest that if attention is focused laterally vs. centrally, a task-irrelevant but incongruent letter sound has increased influence on discrimination performance of attended visual letters, reflected neurally by modulation in the late, but not early, perception-related ERP activity.

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Walking changes perceived visual speed of both expanding and contracting optic flow fields

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Perceived visual speed has been reported to be reduced during walking. This effect has been attributed to subtraction of part of the walking speed from the visual speed (Durgin et al., 2005; 2007). Previously, we have shown that this subtraction only occurs in a restricted range of low visual speeds. For higher speeds, visual speed is judged to be faster during walking than during standing (Souman et al., 2008). Here, we tested whether the effect of walking on perceived visual speed depends on the functional relationship between the two (Exp. 1). We measured visual speed perception for contracting optic flow during forwards walking, in effect reversing the direction of the optic flow relative to the walking direction. Participants compared the visual speed of a ground plane, presented through an HMD, in two intervals: walking or standing. The speed match for three standard speeds (1, 2, 3 m/s) of contracting optic flow was determined in a constant stimuli paradigm. Similar to expanding optic flow, walking caused slow visual speeds to appear slower and fast visual speeds to appear faster relative to standing still. In a second experiment, with expanding optic flow, we measured visual speed discrimination performance to test whether the visual system still has access to the retinal speed signal during walking. In half the trials, walking speed was equal in both intervals (homogeneous), while it differed in the other half (heterogeneous). If the visual system has direct access to the retinal speed, differences in walking speed should not affect discrimination performance. However, we found that discrimination thresholds were significantly higher in the heterogeneous trials, suggesting that the retinal speed signal is not available for speed discrimination.

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Maturation of audiovisual simultaneity judgment

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Our world is inherently multisensory. Our ability to make assumptions about the relatedness of multisensory stimuli is largely based on their temporal and spatial relationships. Stimuli that are proximal in time and space are highly likely to be "bound" together by the brain and thus ascribed to a common external event. While the constraints to multisensory integration have been studied in human and animal models using both behavioral and physiological techniques, little is known about the temporal aspects of multisensory processing in children. Studies comparing behavioral responses of adults to gaze maintenance findings in infants have revealed developmental differences in the range of temporal asynchronies over which audiovisual stimuli are judged as simultaneous. Infants display a higher threshold for detecting interstimulus asynchrony; they bind more temporally disparate stimuli than adults (Lewkowicz, 1996). Previous research has also reported differences between children and adults in processing of coincident auditory-visual stimuli. However, age-related discrepancies in the temporal aspects of multisensory integration have not been investigated. In the current study, we compared behavioral responses of 10 and 11 year-old children to those of adults on a simultaneity judgment measure. Findings revealed differences in the temporal profiles of multisensory integration between younger and older groups. Children were more likely to report stimuli as simultaneous at moderate and long stimulus onset asynchronies (-150 to -450 ms) in conditions where the auditory stimulus preceded the visual cue. Results will provide an empirical foundation for a broader developmental study of the chronology of multisensory temporal processing.

Cross-modal attention in the pause-and-go fan illusion

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Multiple blades of a continuously rotating fan appear to "pause" when they pass behind those of an overlapped stationary fan, giving rise to the overall impression that the fan at the back is rotating jerkily (Peter, 1956). To account for this pause-and-go fan illusion, we propose that the blades of the rotating fan are "collective objects", which tax the same pool of attentional resource used for extrapolating visual motion perception. This hypothesis was supported by results from a series of experiments using an adaptive staircase procedure. The participants were asked to judge the smoothness of the rotating fan, and the point of un-partial ambiguity calculated from the psychometric function was compared across different conditions. The results showed, as predicted, that the perceived jerkiness increased with the number of blades of the rotating fan, and when attention was distracted away from the blades by a visual onset. Whether this attentional modulation of object motion is modality-specific or is shared by different modalities was tested by replacing the visual onset with an acoustic one. The fact that similar results obtained in the visual- and acoustic-onset conditions suggest that cross-modal attentional modulation operates on visual motion of collective objects.

Perception of deceleration during simulated steering by using variation of linear acceleration and tilt

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Tilt-coordination is a commonly used method for simulating a sustained linear acceleration in a dynamic driving simulator. It consists of using the tilt of the simulator in order to orient gravity relative to the driver's head in a similar way as the gravito-inertial acceleration (GIA) is oriented in the real vehicle [1]. According to Groen et al. [1], the key issue of tilt-coordination is to apply sufficient simulator tilt without the angular velocity exceeding the perceptual threshold. Starting from their experiment of using only tilt to simulate acceleration, we developed a new experiment in which we use both linear acceleration and tilt. The final acceleration is simulated using different ratios of linear acceleration and tilt. We inquired if changing the ratio acceleration/tilt will influence the perception of the final acceleration and if this perception is biased by external conditions, like the presence or absence of optical flow. For this, we used a dynamic driving simulator, equipped with an X-Y motion platform and a 6 DOF (degrees of freedom) hexapod [2]. The subjects were submitted to a predefined scenario of linear displacement on a straight road. The scenario consisted of displacement of the car at constant velocity toward a wall and braking at a certain distance before the wall. Simultaneously with the beginning of the braking, the wall disappeared instantly and the subjects were asked to tell if the car stopped before or after the wall. The braking was simulated using 5 different ratios of acceleration/tilt, but the sum of the final deceleration was always the same (-0.8 m/s2). The experiment was divided in two parts, using two different visual scenarios (with and without optic flow during braking). Preliminary results suggest that the braking is perceived stronger as more tilt is used for the simulation and weaker as more linear acceleration is used. In this case, the final perception would depend on the quantity of acceleration and tilt, even if, according to Holly and McCollum [3], they are perceptually equivalent.

[1] E. L. Groen and W. Bles. How to use body tilt for the simulation

of linear self motion. Journal of Vestibular Research, 14(5):375–385, 2004. [2] T. Chapron and J.P. Colinot. The new PSA Peugeot-Citroën Advanced Driving Simulator: Overall design and motion cue algorithm, Proceedings for Driving Simulation Conference North America, Iowa, USA, 2007. [3] J.E. Holly and G. McCollum. The shape of self-motion perception – I. Equivalence classification for sustained motion. Neuroscience. 70(2):461-486,1996.

Visual freezing effect by sound in infants

Yuji Wada [1], Nobu Shirai [2, 3], Yumiko Otsuka [4, 3], So Kanazawa [5], Masami K Yamaguchi [6]

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In adult, a salient tone embedded in a sequence of non-salient tones improves detection of a synchronously presented brief visual target in rapid visual distracting sequence (Vroomen & de Gelder 2000). Wada et al., (2009) reported that audio-visual enhancement in visual detection is emerged at 7 month of age using illusory-contours composed of 4 packmen as visual target. However, it is still unclear whether the finding would be related to the multisensory perceptual organization or that would reflect the development of attention. Here, we examined these issues with 2 experiments. We used a preferential looking technique to investigate whether audio–visual enhancement of the detection of visual target could be observed at 5, 6, and 7 months of age. In the first experiment, we used a non-illusory target: each packman kept their back to the others. In the second experiment the salient sound was presented together with the distractor just before the target illusory-contour figure. Results indicated that the preference for targets was significant only in 7-month-olds in the first experiment. No audio-visual enhancement was observed in the second experiment. These results confirm the audio–visual enhancement in visual target detection emerges as multisensory organization at 7 months of age.

Short-term Memory Representation of Tactile Stimuli to Fingertips

Yuki Miyazaki [1], Takako Yoshida [2], Hiromi Wake [3], Tenji Wake [3], Shigeru Ichihara [1]

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We examined whether the representation held in the short-term memory of simultaneously presented tactile stimuli to fingertips is individual representation or integrated representation between each digit. To determine this, we used the change detection paradigm. In this paradigm, two stimulus arrays are presented sequentially, and observers are required to report whether a change has occurred between them. The performance of this discrimination is assessed as a function of the number of items in the stimulus array so as to determine how many items could be accurately retained in the short-term memory. The results showed that the representation of tactile stimuli to fingertips held in the short-term memory seems to be integrated representation between each digit, after bilateral integration. We believed that this representation is not reflected in topical and fine-scale somatotopy, for example in area 3b of the primate primary somatosensory cortex. It was found that the representation held in the short-term memory of tactile stimuli to fingertips is not a pure replica of the external world.

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Bayesian integration of visual and vestibular signals for heading

John S Butler[1], Jennifer L. Campos[1], Heinrich H. Bülthoff[1], Stuart T Smith[2]

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Building upon recent results which have shown that visual and vestibular signals combine in a statistically optimal fashion for heading, we investigate the relative weights of visual and vestibular cues during self-motion. To do investigate this, participants performed a 2-interval forced choice task (2IFC) in all conditions in which they were asked to judge "in which of the two intervals did you move more to the right". To observe the weights assigned to each modality we introduced a discrepancy between the visual and vestibular cues in the standard visual-vestibular heading. The experiment comprised of nine conditions: vestibular alone, four visual alone at different standard headings and four visual-vestibular with small and large conflict levels ($\Delta = \pm 6°$ or $\pm 10°$) between the visual and vestibular input. We found that even when there is a large conflict between the visual and vestibular cues; participants exhibit statistically optimal reduction of variance of visual and vestibular information. On the other hand, we found that the unimodal cues did not predicted the weights in the combined cue. We conclude that visual and vestibular cue combination is not predicted solely by the reliability of each cue but that there is a prior which lends more weight to the body centric cue.

DAY 3 - WEDNESDAY

Elucidating the correlates of the multisensory perception of naturalness

T Aisling Whitaker, Cristina Simoes-Franklin, Fiona N Newell

Trinity College Dublin

The ability to readily discriminate between natural things and synthetic mimics in the environment is a skill which is not only important for the survival of many species but also has significant consumer value. The ability to discriminate between real and fake relies on the acuity of the different senses, the material characteristics of the stimuli, past knowledge and experience and the goal of the behavior. In a large study, conducted as part of a science exhibition, we investigated the relative contribution of vision and touch to the categorization of a set of different fabric stimuli as natural. The stimuli were comprised of 44 fabric samples, which varied systematically from natural to synthetic. We also examined whether this categorization performance correlated with other more higher-order judgments such as pleasantness, familiarity, softness, value and hedonics using a 7-point scale. We found that perceived naturalness was strongly correlated with both value and hedonics. Specifically, natural stimuli were rated as more valuable and were liked more. In a second experiment, we examined the brain activations associated with the perception of naturalness using a subset of these stimuli and cross correlated these activation with ratings of value and hedonics. We found that whilst each modality contributes to the perception of naturalness independently, there is some evidence for multisensory contributions to the perception of naturalness. Although other correlates of naturalness differentially affected brain activations these differences were not generally observed in sensory cortices. These results have implications on our understanding of how the senses contribute to more higher-order decisions related to the perception of texture.

Affective expression as multisensory binding feature in a ventriloquist situation

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Multisensory illusions have often been used to study the principles of multisensory binding processes. For example, when a central sound is paired with two lateralized visual stimuli, the sound is perceived at the location of the matching visual stimulus. This effect is well known as the ventriloquist illusion and is thought to indicate the dominance of vision for sensory localization. The present study had two goals: (1) to test whether affective expression is capable to act similarly as temporal synchrony as supramodal binding feature; (2) to establish a paradigm that allowed measuring the ventriloquist illusion response-bias free.

Two movies of a speaker were presented one in the left and in the right hemifield; the sound was presented form a central location. The actors spoke bi-syllabic pseudo-words. In the experimental condition, one face matched the voice while the other face did not match the spoken word. The match consisted either of speaking the same vs. a different word or of speaking the same word with the same or a different affective expression. The participants had to decide whether the word was spoken with a loud or a low voice. If a ventriloquist effect occurred based on temporal or affective binding, respectively, we expected response times to be lower for loud-low decisions that required a response with the ipsilateral hand, thus we predicted a Simon effect to occur. We ran a number of control conditions including a real lateralized presentation of the voice. Results showed a Simon effect both for the temporal and affective ventriloquist conditions although smaller than for the real lateralized control conditions.

Thus, we established a paradigm that allows accessing the ventriloquist effect response bias free. Moreover, we demonstrated automatic multisensory binding based on affective expression.

What perspective do people take when interpreting tactile letters presented on their bodies?

Malika Auvray [1], Charles Spence [2]

[1]CNRS UMR8119 Alberto Gallace, Dipartimento di Psicologia, Universita' degli Studi di Milano Bicocca, [2]Crossmodal Research Laboratory, Department of Experimental Psychology, Oxford University

We report a study designed to investigate the perspective that people take with respect to letters drawn on their body surface: Are the letters perceived from an external point of view (i.e., as if located in front of the observer) or from an internal point of view (i.e., as 'mirror reversed'). We investigated the perspective taken by participants as a function of 3 parameters: Letters location (the letters were presented on the back or stomach), letter presentation (the letters were drawn from top-to-bottom or from bottom-to-top), and gaze direction (the participants were sometimes able to view the stimulated body part). In Experiment 1, the participants were presented with letters drawn on their stomach by means of a tactile 'corset' consisting of a 3x3 array of 9 vibrators. The participants made normal vs. mirror-reversed (i.e., left/right reversed) judgments concerning the letters C and L presented either 'Normal' or 'Mirror reversed'. The participants completed the task while looking to the front, while looking down at their stomach, or while looking at the mirror image of their stomach in a mirror placed directly in front of them. Each condition was run with the two target letters drawn either from top-to-bottom or from bottom-to-top. In this, and in all the experiment reported here, there was no main effect of Gaze direction on the RT or error data. A significant effect of Letter direction in the error data reflected the fact that participants were more likely to consider the letters from an external point of view when presented from top-to-bottom (77%) than when presented from bottom-to-top (69%). The RT data revealed a similar pattern of results with participants responding faster for the letters presented from top-to-bottom.

In Experiment 2, participants performed the same task with the letters being presented on their back. The participants either looked at a blank screen or else at a real-time video recording of their back presented on the screen. The participants nearly always considered the letters from an external point of view. With respect to RTs, consistent with Experiment 1, the results revealed a significant effect of Letter direction with the participants responding faster for the letters presented from top-to-bottom. Finally, in Experiment 3, the participants had to recognize the letters b, d, p, and q that were presented either on their stomach or back, while looking either at a blank screen or at the stimulated body part (i.e., the back or stomach) on the screen. Participants responded more rapidly when the letters were presented on their back than when they were presented on their stomach. Overall, this study revealed that the participants most often adopted an external point of view (i.e., they perceived the letters as being located in front of them) rather than an internal point of view. However, participants made more consistent (and faster) judgments for letters presented on their back than on their stomach. They also responded more rapidly to letters presented from top-to-bottom than from bottom-to-top. Performance was not influenced by whether participants viewed the stimulated body part or not.

10th International Multisensory Research Forum

DAY 3 - WEDNESDAY

Auditory Effects on the Timing of Exogenous and Endogenous Visual Attention

Mirjam Keetels, Jean Vroomen

Tilburg University

The authors explored the effect of sound on the timing of exogenous and endogenous visual attention. Twelve clocks arranged in a circle around central fixation revolved in clockwise direction with randomly determined initial positions (Carlson et al., 2006, Journal of Vision). The participant's task was to report the hand position of a target clock at the time that an exogenous cue (one clock turning red for 100 ms) or an endogenous cue (a line pointing from fixation towards one of the clocks) was presented. An auditory click was presented either 100 ms before, simultaneously, or 100 ms after the cue. In a silent control condition, endogenous cues resulted in a larger lag of the clock's hand from actual position (> 200 ms) than exogenous cues (~80 ms). A simultaneous sound improved accuracy for both cues, and a click before or after the cues shifted the lag in that direction. Sounds thus affected the timing of exogenous and endogenous visual attention.

Symposium 5: The Development of Multisensory Integration

10:30 – 12:30

Organised by David J. Lewkowicz, Florida Atlantic University

Chair: David J. Lewkowicz, *Florida Atlantic University*

Speakers:
Mark Wallace, *Vanderbilt University*

Robert Lickliter, *Florida International University*

Lorraine Bahrick, *Florida International University*

Asif A. Ghazanfar, Princeton University

Bruce D. McCandliss, *Vanderbilt University*

Overview:
To achieve a coherent perceptual synthesis, developing organisms must be able to perceive the intersensory relations inherent in the sensory attributes that specify their multisensory world. This symposium explores the comparative aspects of the development of multisensory integration by considering this process in three different species: human infants, monkeys, and cats and focuses on the development of multisensory integration at the behavioral and neural levels. Lickliter and Bahrick will discuss the importance of intersensory redundancy in directing selective attention in human infants and will delineate a model that predicts under what conditions perceivers selectively attend to redundantly specified vs. nonredundantly specified stimulus attributes. Lewkowicz will discuss recent findings from his laboratory showing for the first time that human infants begin life with a broadly tuned perceptual system that is sensitive to native as well as nonnative multisensory inputs and that as development progresses this sensitivity narrows as a function of experience with native multisensory inputs. Ghazanfar will consider the evolution of multisensory systems with an eye towards determining whether comparative studies of their ontogeny can provide insights into behavioral and neural homologies and will show that developmental timing and experience differentially affect

the formation of multisensory circuits across different species. Wallace will discuss his findings on the development of multisensory circuits at the cortical and subcortical levels and will show that these circuits are not present at birth, mature over time, and are dramatically shaped by early sensory experience. McCandliss will serve as the discussant for this symposium, and in addition to synthesizing the presentations will relate these studies to his work examining the development of the multisensory brain networks that subserve reading.

Symposium 5: The Development of Multisensory Integration

A Framework for the Development of Intersensory Perception: Four Predictions of the Intersensory Redundancy Hypothesis

Robert Lickliter and Lorraine Bahrick

Infant Development Research Center, Florida International University

Intersensory redundancy is provided when the same amodal information (rhythm, tempo, duration, intensity changes) is simultaneously available and temporally synchronized across two or more sensory modalities. Most naturalistic, multimodal events provide intersensory redundancy for amodal stimulus properties as well as nonredundant modality specific information, such as the visual appearance of a face or the acoustic qualities (pitch, timbre) of a voice. What guides selective attention to these various properties of events during early development? We have proposed and provided empirical support for the Intersensory Redundancy Hypothesis (IRH), a model of selective attention comprised of a set of principles that predict and explain under what conditions perceivers attend to and process different properties of events, redundantly specified vs. nonredundantly specified. The IRH consists of four specific predictions: two predictions address the nature of selective attention to amodal vs. modality-specific properties of events and two are developmental predictions that address implications across the lifespan. We review these four predictions and discuss how they have been supported by empirical studies with both non-human animal infants and human infants. Our results suggest (1) amodal properties of events are more likely to be detected in multimodal stimulation and modality-specific properties in unimodal stimulation, (2) these processing biases lead to general salience hierarchies in attentional allocation, (3) these salience hierarchies exert a disproportionately large effect in early development, when attentional resources are most limited and cognitive load is highest, and (4) these hierarchies can continue to exert influence on later development when cognitive load and task difficulty are high. Because selective attention provides the basis for what is perceived, learned, and remembered, patterns of early selectivity can have long term, organizing effects on the development of knowledge across the life-span.

Symposium 5: The Development of Multisensory Integration

Narrowing of Intersensory Perception in Early Development

David J. Lewkowicz

Florida Atlantic University

The conventional view in developmental theory is that sensory, perceptual, and cognitive functions improve and broaden in scope as infants grow and mature. Despite this view and despite an overwhelming empirical base attesting to this fact, a small but steadily growing behavioral literature has shown that some auditory and visual perceptual functions actually decline in early life and that this is due to the effects of specific perceptual experience. Until now, the evidence of such a decline has come strictly from studies of infant response to unisensory information raising questions about the generality of this process. Recently, however, our studies have provided the first evidence of such a decline in the intersensory domain by showing that intersensory perception undergoes experience-dependent narrowing as well and, thus, that perceptual narrowing is a pan-sensory, general developmental process. I will review this new evidence by discussing the results of our studies showing that (a) 4-6 month-old infants can integrate the faces and vocalizations of a nonnative species but that infants older than 8 months of age no longer do, (b) the broad intersensory perceptual tuning first identified in young infants is present at birth, (c) intersensory perception of nonnantive audiovisual speech also narrows in infancy, and (d) the narrowing of intersensory perception is a relatively novel evolutionary innovation. I will conclude by suggesting that early perceptual experience, together with an initially unusually broad sensitivity to native as well as nonnative intersensory relations, contribute in critical ways to the development of mature intersensory perceptual expertise.

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Symposium 5: The Development of Multisensory Integration

Developmental timing and the evolutionary emergence of multisensory systems in primates

Asif A. Ghazanfar

Princeton University

Understanding the evolutionary origins of multisensory systems requires an understanding of how such systems develop. The relationship between ontogenetic processes with phylogenetic ones can inform questions about whether humans and other primates share homologous behaviors and whether these behaviors are mediated by homologous neural mechanisms. All primate species tested thus far show the ability to match the faces and voices of conspecifics. This raises the question: are the developmental processes leading to the emergence of these abilities similar or different across species? The most likely answer is that because the rate of neural development in Old World monkeys and humans differs, the developmental emergence of multisensory integration probably also differs. I will present data on the comparative development of multisensory perceptual narrowing in vervet monkeys, an Old World species. The results suggest the multiple mechanisms by which developmental timing and experience can influence the formation of multisensory circuits.

DAY 3 - WEDNESDAY

Symposium 5: The Development of Multisensory Integration

Development of Multisensory Cortical and Subcortical Representations

Mark Wallace

Vanderbilt University

Multisensory circuits at various levels of the nervous system are specialized for the integration of convergent information from multiple sensory modalities. Recent work in animal models has highlighted that these circuits are not present at birth, but rather appear and mature during early postnatal life. In comparing the maturational profiles for cortical (i.e., anterior ectosylvian sulcus) and subcortical (i.e., superior colliculus) multisensory structures, there is a gradual chronological progression in the development of multisensory neurons in both structures, with cortex lagging subcortical development by several weeks on various maturational indices. Although both structures are exclusively unisensory immediately after birth, as development progresses multisensory neurons gradually appear. These first multisensory neurons differ from their adult counterparts in having very large receptive fields and lacking integrative capacity. With increasing age receptive fields become smaller and integrative capacity appears. Recent analyses further specify this developmental process by illustrating the transition in receptive field architecture from large and fairly homogenous at early ages to small and markedly heterogeneous a bit later. Together, these results highlight a strong linkage between receptive field consolidation and the appearance of integrative capacity, suggesting similar mechanistic underpinnings to these important developmental events.

Oral Session 3: Development

2:00 – 4:00

2:00 – 2:20

The Illusory Flash Effect in school-aged children reveals developmental changes in auditory dominance

Elena Nava, Gabriella Gloria Scala, Francesco Pavani

University of Trento

Our perception of the world is clearly multisensory, but the weight that a single sensory modality adds to the final percept is sometimes difficult to determine. A simple way to investigate this issue has been to present conflicting sensory modalities, and to observe the sensory preference. For instance, the Illusory Flash Effect reported by Shams et al. (2002) shows that whenever a visual stimulus is presented together with one or more auditory beeps, adult participants tend to perceive multiple flashes. While the interaction between senses has been largely studied in the adult population, the development of non-linguistic sensory perception in school-aged children has remained underinvestigated. Recent studies have shown that children up to 4 years of age have an overall preference for auditory inputs (Robinson & Sloutsky, 2003). However, it remains to be ascertained how this auditory dominance may change during development.

Here we investigated audio-visual interactions in a developmental perspective, by testing the Illusory Flash Effect in school-aged children of 6, 9 and 11 years old. We adopted this paradigm (that avoids linguistic stimuli) under the assumption that auditory preference should be stronger in children of 6 years of age, and progressively decrease with age given that the overall sensory preference in adulthood typically favours the visual modality. Visual stimuli consisted of a uniform yellow disk subtending 2° of visual field presented in the centre of the computer monitor. Auditory stimuli consisted of an 80 dB beep (4 kHz). Visual stimuli could be presented either alone (unisensory conditions: 1, 2 or 3 flashes) or combined with 1, 2 or 3 auditory beeps (multisensory conditions). Children sat approximately at 60 cm from the monitor and were asked to type on

the keyboard the corresponding number of perceived flashes.
Results showed that all three groups of children presented an illusory effect. However, 6-year-old children made more illusory fusions (i.e., less flashes than actually presented) than the other two groups when 2 or 3 flashes were paired with 1 beep. Similarly, 6-years-old children made more illusory fissions (i.e., more flashes than actually presented) than the other two groups, when 1 flash was presented together with 2 or 3 beeps. Because all children recognised single flashes equally well when presented unimodally, the latter result particularly indicates that more illusory mistakes in 6-years-old cannot be reduced to counting difficulties.
Our results support the existence of different maturational patterns for auditory and visual modalities. Auditory preference decreases with age, switching towards an overall visual preference. This pattern may be a consequence of visual abilities improving with age, due to reading and speech skills learned at school, and that mainly rely on vision. Finally, although speculative, there may be attentional changes that occur with age, that automatically shift attention towards the preferred sensory modality.

Oral Session 3: Development

2:20 – 2:40

The breakdown of multisensory speech perception in autism and schizophrenia

John J Foxe [1], Lars Ross [2], Dave Saint-Amour [3], Victoria Leavitt [3], Daniella Blanco [1], Sophie Molholm[1]

[1]City College of New York, [2]Temple University, [3]NKI

Viewing a speaker's articulatory movements can greatly improve a listener's ability to understand spoken words, and this is especially the case under noisy environmental conditions. We have shown that there is a very specific tuning function to this multisensory gain, with audiovisual enhancement showing its maximum effect at fairly specific signal-to-noise (SNR) ratios (Ross et al. 2007a, Ma et al., 2009). Thus, while multisensory gain is seen across a host of SNRs, it is also evident that there is a 'special zone' at a more intermediate SNRs (approximately –12dB) where multisensory integration is additionally enhanced. At these intermediate SNR levels, the extent of multisensory enhancement of speech-recognition is considerable, amounting to more than a threefold performance improvement relative to an auditory-alone condition. Our data show that the multisensory speech system develops this maximal tuning relatively slowly across the childhood years and that considerable tuning continues to occur into early adolescence. More recently, we have translated this basic knowledge into the clinical domain, testing multisensory speech perception in a cohort of patients with schizophrenia and also in a pilot study of high functioning autistic children. In the first of these studies, we assessed the ability to recognize auditory and audiovisual speech in different levels of noise in 18 patients with schizophrenia and compared their performance with that of 18 healthy volunteers (Ross et al., 2007b). We used a large set of monosyllabic words as our stimuli in order to more closely approximate performance in everyday situations. Patients with schizophrenia showed deficits in their ability to derive benefit from visual articulatory motion. Crucially, this impairment was most pronounced at the intermediate SNR levels where multisensory gain is maximally tuned in healthy control subjects. A surprising finding

was that despite known early auditory sensory processing deficits and reports of impairments in speech processing in schizophrenia, patients' performance in unisensory auditory speech perception remained fully intact. The results showed a specific deficit in multisensory speech processing in the absence of any measurable deficit in unisensory speech processing and perhaps more interestingly, that this appeared to be mainly a result of a failure to tune the system appropriately. These data suggest that sensory integration dysfunction may be an important and, to date, rather overlooked aspect of schizophrenia. We have recently followed this work up in a small cohort of high functioning autistic children. Sensory integration dysfunction has long been speculated to be a core component of autism spectrum disorder but there has been precious little hard empirical evidence to support this notion. In this pilot study, we find considerable reduction in multisensory gain in ASD children relative to age and IQ matched controls. This deficit becomes progressively more pronounced at lower SNRs. Ma WJ, Zhou X, Ross LA, Foxe JJ, Parra LC. Lip-reading aids word recognition most in moderate noise: a Bayesian explanation using high-dimensional feature space. PLoS ONE. 2009;4(3):e4638.

Ross LA, Saint-Amour D, Leavitt VM, Javitt DC, & Foxe JJ. Do you see what I am saying? Exploring visual enhancement of speech comprehension in noisy environments. Cereb Cortex. 2007a May;17(5):1147-53.

Ross LA, Saint-Amour D, Leavitt VM, Molholm S, Javitt DC, & Foxe JJ. Impaired multisensory processing in schizophrenia: deficits in the visual enhancement of speech comprehension under noisy environmental conditions. Schizophr Res. 2007 Dec;97(1-3):173-83.

Oral Session 3: Development

2:40 – 3:00

The development of visual-proprioceptive integration in reaching in typically developing children and children with a diagnosis of Developmental Coordination Disorder (DCD)

Andrew J. Bremner [1], Michelle Pratt [1],
Charles Spence [2], Elisabeth L Hill [1]
[1]Goldsmiths, 1University of London, [2]University of Oxford

In adult humans, vision plays a dominant role in determining both the perceived location of the arms when stationary, and in controlling reaching (Holmes et al., 2004). It has been argued that vision becomes more important than proprioception in localization as a function of the increased visual experience typically obtained during childhood. We report data assessing the development of visual dominance in the control of reaching in children diagnosed with developmental coordination disorder (DCD; n=10) in comparison to age and IQ-matched typically developing group (45 children aged 6-12 years) and adults (n=15). Participants completed Holmes et al.'s (2004) mirror reaching task. In this task, participants viewed their left arm on both sides of their midline (by virtue of a mirror placed at the midline facing the left arm, and obscuring the right arm) and were asked to reach with their right (hidden) hand for a target placed 25cm in front of that hand. Reach accuracy was measured when proprioceptive and visual cues to the location of the right hand were placed in varying degrees of intersensory conflict (by moving the hidden hand in the azimuthal plane with respect to the mirror image of the left hand) and also when no visual information concerning the location of the hand was made available (by covering the mirror). Results indicate that all groups showed comparable visual capture effects (as demonstrated by a greater reliance on visual cues in the mirror even when these were misleading). However, the DCD group was more impaired at reaching accurately in the absence of visual information about their hand (i.e. when the mirror was obscured). We will discuss the implications of these findings regarding the development of multisensory representations of the body in typically developing individuals and individuals with DCD.

Holmes, N.P., Crozier, G. & Spence, C. (2004). When mirrors lie: "Visual capture" of arm position impairs reaching performance. Cognitive, Affective, & Behavioral Neuroscience, 4, 193-200.

Oral Session 3: Development

3:00 – 3:20

Audio-visual integration in fall-prone older adults

Annalisa Setti, Kate E. Burke, RoseAnne Kenny, Fiona N. Newell

Trinity College Institute of Neuroscience

Recent studies have suggested that parsing of multisensory stimulation for efficient attentional allocation is compromised in older adults (Poliakoff et al., 2006). In our study, we investigated the effiency of multisensory integration as a consequence of ageing. We also explored whether inefficient multisensory perception is associated with impaired actions, such as maintenance of balance and gait. Although the association between unisensory degradation and the incidence of falls has already been shown, it is not known whether the integration between sensory inputs is specifically compromised in fall-prone older adults. Here we assessed multisensory efficiency in three groups of participants, fall prone and non fall prone older adults and young adults, using a well-known sound induced visual illusion (Shams et al., 2000). Age, auditory acuity, visual acuity, contrast sensitivity and cognitive functions (assessed through the Mini Mental State Exam) were balanced across older participants.

In the first experiment the number of beeps and flashes was manipulated to assess both the fission (e.g. 1 flash presented with 2 beeps are perceived as 2 flashes) and the fusion illusion (e.g. 2 flashes presented with 1 beep are perceived as 1 flash). The results showed that fall prone older adults were the only group of participants to experience both kinds of illusions.

In the second experiment we assessed whether the temporal window of integration differs across the three groups. It has been shown that older adults have a more extended window of integration (Diedrich et al., 2008). In the present study we presented 1 flash with 2 beeps and we manipulated the SOA between the two beeps from 30ms to 270ms. We found that older adults in general integrate auditory and visual inputs over longer SOAs than younger adults. Moreover, fall prone older adults integrate auditory and visual inputs over a larger temporal window compared to non fall prone older adults. Our findings suggest that ageing is associated with inefficient unisensory processing from multisensory stimulation and that such inefficient perception may account for impaired actions. These results have significant implication for diagnosis and rehabilitation of fall prone elderly.

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DAY 3 - WEDNESDAY

Oral Session 3: Development

3:20 – 3:40

Development of variance reduction by cue integration between and within modalities

Marko Nardini, Rachael Bedford, Denis Mareschal

Birkbeck College, University of London

Sensory estimates are limited in resolution and corrupted by noise. When multiple cues to the same property are available, such as visual and haptic cues to shape, it is possible to improve the accuracy (reduce the variance) of the final estimate by integrating these individual estimates [1]. Recent research shows human adults to be proficient at integrating multisensory cues in a manner that is optimal for reducing variance. This entails averaging the cues while taking their individual reliabilities into account. We will present two studies examining the developmental basis for this ability. Even young infants know the correspondences between multisensory stimuli, and respond more rapidly to multimodal than unimodal events. We asked whether these early-emerging multisensory capacities provide a basis for optimal integration based on cue reliability, or whether this kind of integration depends on a different, still unknown developmental process.

We first tested 4-8 year olds' and adults' accuracy in homing to a location in a darkened room using (i) visual landmarks and (ii) the internal sense of direction updated with self-motion (e.g. vestibular) cues, when these were presented either separately, together, or under a small conflict [2]. While adults integrated landmark and self-motion information near-optimally to reduce the variance of their spatial estimates, children as old as 8 years did not integrate the cues but followed one or the other. This suggests a surprisingly late development for integration of visual and vestibular spatial cues. We followed this up with a study posing the same information-processing problem in a different way: a psychophysical two-alternative-forced-choice (2AFC) task with minimal motor and memory demands, testing how accurately participants could judge the slants of surfaces based on disparity and texture– two cues within the visual modality. When both disparity and texture cues were available, adults integrated these to reduce the variance of their estimates of surface slant. By contrast, children as old as 10 years did not show a significant improvement given both cues together rather than one alone.

Taken together, these results suggest that young children either (1) cannot compute weighted averages based on multiple cues, or (2) use a perceptual decision rule (criterion for how much sensory evidence to correct before responding) that is optimised for speed rather than accuracy. I will discuss some experimental and modelling work on the time course of perceptual decisions based on multiple cues that addresses this second hypothesis.

[1] Ernst, M. O. & Banks, M. S. (2002). Humans Integrate Visual and Haptic Information in a Statistically Optimal Fashion. Nature, 415, 429-433.

[2] Nardini, M., Jones, P., **Bedford, R.**, & Braddick, O. (2008). Development of Cue Integration in Human Navigation. Current Biology, 18, 689-693.

10th International Multisensory Research Forum

DAY 3 - WEDNESDAY

Oral Session 3: Development

3:40 – 4:00

Age differences in the pattern of benefit of audio-visual speech perception in younger and older adults

Natalie Phillips [1], Jean-Pierre Gagné [2], Madhavi Basu [1], Laura Copeland [3], Penny Gosselin [4], Arnaud Saint-Pierre [1], Axel Winneke [1]

[1]Concordia University, [2]Université de Montréal, [3]McGill University, [4]Université de Montréal

Background and Purpose: Older adults (OAs) perform more poorly than young adults (YAs) on speech understanding tasks, even with clinically normal audiograms. However, speech perception can be enhanced when one can both hear and see the speech cues produced by one's communication partner. Using auditory (A) and visual (V) information to understand speech is referred to as audio-visual (AV) speech perception. The purpose of this study is to describe and understand aspects of bimodal speech integration in YAs and OAs by investigating the sensory, perceptual, and cognitive processes involved in AV speech perception.

Methods: Young (n=19; mean age = 22 yrs; 3 males) and older (n=19; mean age = 69 yrs; 3 males) normal hearing adults were asked to identify words terminating low and moderately constrained sentences under A-alone, V-alone, and AV conditions. A and AV conditions were presented in a multi-talker masking noise. In order to induce a similar perceptual load in both groups, the signal-to-noise ratio was titrated to produce a 50% error rate in the A-alone low context condition.

Results: Word identification improved across modality (means: V= 22%, A= 54%, AV= 87%, respectively; $F(2,72)=753$, $p<.001$), and there was a significant effect of Context ($F(1,36)=21.8$, $p<.001$), indicating improved performance for moderate- (mean = 52%) versus low-constraint sentences (mean = 58%). The Modality X Context interaction ($F(2,72) = 14.4$, $p<.001$) indicated an effect of context for the A and AV modalities only. Although young adults performed better than older adults overall (mean = 58% vs. 51% respectively), both groups showed a significant AV improvement. When the visual enhancement effect was calculated as a function of the relative gain over A-alone performance, YAs showed a greater improvement over baseline ($F(1,36) = 6.2$, $p=.018$). We also tested memory performance for terminal words that were identified in our experimental sentences. There was a strong trend towards a significant Modality X Group interaction ($F(2,62) = 2.76$, $p=.071$). This revealed that OAs remembered more terminal words when they were presented in AV mode than V mode, a faciliatory effect of mode was not present in the YAs.

Conclusion: Our findings indicate that, although both age groups used visual speech cues to enhance speech perception, the younger adults show a greater benefit in word recognition per se. However, presenting speech bimodally facilitated memory for information for OAs but not for YAs. These results suggest that processing speech in the AV modality is less perceptually demanding and can free resources for higher order processes like memory.

10th International Multisensory Research Forum

DAY 3 - WEDNESDAY

KEYNOTE ADDRESS
4:30 – 5:30

Multisensory Integration: Current Results and Future Methodologies

Prof. Nikos K. Logothetis

MPI for Biological Cybernetics

Recent results from human imaging and electrophysiology demonstrate that the processing of acoustic information can be influenced by stimulation of other sensory modalities already at early stages in auditory cortex. For example, auditory responses of neurons in primary and secondary fields are enhanced or reduced by the simultaneous presentation of visual or touch stimuli. Although often denoted as sensory integration, the exact function of these multisensory influences is unclear, and it remains to be shown whether they actually make the auditory neurons more reliable or informative about the acoustic environment. In my talk I shall first discuss neuroimaging and electrophysiology results related to the process of sensory integration, and subsequently I'll describe two multimodal approaches for the study of in vivo connectivity, that can greatly facilitate the study of sensory integration.

Day Four
Thursday July 2nd 2009

9:00 –10:30	**Posters IV (coffee/snack)**
10:30 –12:30	**Oral Session 4: Modelling and brain mapping**
12:30 –2:00	**Lunch – buffet style at quad** **Business meeting: (1:30 – 2:00)**
2:00 –4:00	**Symposium 6: Plasticity and synergy in multisensory integration –** **Chaired by Barry Stein**
4:00 – 4:30	**Coffee/snack**
4:30 -6:00	**Oral session 5: Other**

Posters IV
July 2nd 2009
9:00 – 10:30

Effective connectivity of human lateral occipital complex (LOC) during visuo-haptic object perception

Jasper J.F. van den Bosch, Yavor Yalachkov, Oliver Doehrmann, Jochen Kaiser, Marcus J. Naumer,

Institute of Medical Psychology, Goethe University Frankfurt

In the human brain, visuo-haptic (VH) object perception involves a distributed network of functionally connected cortical as well as subcortical regions. In order to investigate directed influences (i.e., effective connectivity) between these regions we applied hypothesis-generating Granger causality mapping (GCM) to an fMRI data set acquired during visual, haptic, and visuo-haptic object perception. Wooden 3D objects (so-called 'fribbles') were presented either unimodally (V; H) or bimodally (VH). In addition, we controlled for potential cue and motor confounds using a 'no-object' baseline condition (M). Effects of VH integration (M<V<VH>H>M) were found in a network of brain regions including left LOC, bilateral IPS, and the lateral cerebellum, bilaterally. These regions were used as so-called seed regions for subsequent GCM. Preliminary results showed that LOC activation is predicted more reliably during unimodal haptic as compared to unimodal visual stimulation. During bimodal VH stimulation, however, LOC activation is predicted best by several cortical as well as subcortical regions. Based on additional (including hypothesis-testing) analyses we will report comprehensive results for all seed regions used.

Orienting endogenous attention to our own and other's body representations

Clara Aranda, Maria Ruz, Daniel Sanabria, Manos Tsakiris, Pio Tudela

The present study comprises a series of four experiments that investigate the effects of voluntary attention on distinct representations of body parts. On the one hand, our research follows up the classical study of attentional processes, as one of its aims is to clarify whether humans are able to orient themselves to particular exemplars of a same perceptual category. On the other hand, it provides a revolutionary way to research self and other's body representations, investigating how the previous activation of these two different schemes could influence the visual perception of self and other-related stimuli. In order to achieve our goals, we used an adaptation of the Cost and Benefits attentional Paradigm (Posner, 1980) where a coloured cue predicted (80% probability) the nature of the hand target (own vs. other), leading to valid (expected) and invalid (not expected) trials. Participants had to judge whether the presented forelimb was a left or a right hand independently of its identity. Our main hypothesis proposed that the subjects would be able to orient themselves either to Own or Other's representation. However, we also suggested a differential development of these two attentional effects. Experiment 1 revealed a significant Status (Own vs Other hand) x Validity (Valid vs Invalid) interaction, showing an orienting effect exclusively present in self-related stimuli. Experiment 2 explored an alternative explanation of these results in terms of own-hand motor activation, in contrast to a more traditional interpretation as a facilitation of visual processing. The results of this second experiment replicated those of Experiment 1. In the first two experiments, participants performed a recognition task prior to the proper experiment in which they only responded to their own hand. Experiment 3 revealed that Other's hand representation is also susceptible to be developed, manipulating implicitly the perceived value of the target. The target value was modified by means of asking participants to respond to both stimuli (Own and Other hand) in the recognition block of trials. In light of results, Experiment 4 investigates whether the attentional orientation effect to our own and Other's body parts relies on different processes. In conclusion, the results of this set of experiments provides promising initial data in the research addressing the attentional modulation of the representations of our own and other's body, offering a new perspective to explore Self and Others distinction.

Combining hypothesis-generating and hypothesis-testing tools during analyses of multisensory fMRI data

Marcus J. Naumer [1], Jasper van den Bosch [1], Michael Wibral [2], Axel Kohler [3], Wolf Singer [3], Jochen Kaiser [1], Vincent van de Ven [4], Lars Muckli [5]

[1]Institute of Medical Psychology, Goethe University Frankfurt, [2]Brain Imaging Center, Goethe University Frankfurt, [3]Max Planck Institute for Brain Research, [4]Faculty of Psychology, Maastricht University, [5]Department of Psychology, University of Glasgow

In this study, we aimed to reveal networks of brain regions that were functionally connected during object-related audio-visual (AV) integration. To this end, we used spatial independent component analysis (sICA), a multivariate, data-driven analysis technique that decomposes an fMRI dataset into spatially independent components, which can be interpreted as functional connectivity maps. Each component was associated with a single time course. These component time courses were then tested using the knowledge about the stimulation time course, thus enabling a classification of components as mainly visual, auditory, or multisensory, amongst others (like physiological components related to breathing and heart beat, or otherwise unmodeled sources). Regions-of-interest (ROIs) were defined as clusters of voxels which contributed significantly to at least two of the three above-mentioned components of interest, in other words, they were the regions of overlap of the component maps.

Voxel time courses can be thought of as the sum of all component time courses weighted by the values of the respective component maps at that voxel. This can result in a variety of voxel characteristics: Voxels in a region where only one spatial component has large map values will show a time course very similar to the respective component time course, e.g. mainly auditory or visual activity. Due to the weighted mixing of components, both visual and auditory unisensory components can contribute equally to a voxel time course. In a GLM analysis the effects of auditory and visual stimulation may be simply additive at this voxel. If the mixing comprises non-zero coefficients for components that describe purely multisensory processing, i.e. processing that is absent during unimodal stimulation, the respective voxel will show superadditive effects. Thus sICA provided us with a set of hypotheses regarding these ROIs.

In order to explicitly test these hypotheses we analyzed the data of an independent experiment 2 in these ROIs using the knowledge of the stimulation time course of this experiment via a massively univariate (hypothesis-testing) voxel-based GLM. Applying the max-criterion (i.e., 0<A<AV>V>0) revealed robust AV integration effects in the ICA-defined bilateral cortical network (consisting of pSTS, VOT, PPC, and PFC regions), thus demonstrating the sensitivity and value of the proposed analysis approach.

10th International Multisensory Research Forum

DAY 4 - THURSDAY

Temporal influence on bimodal multisensory processing in the lateral rostral suprasylvian sulcus (lrss) of the ferret

Leslie P Keniston, Brian L Allman, M. Alex Meredith

Virginia Commonwealth University School of Medicine

The rostral portion of the ferret suprasylvian sulcus divides somatosensory S1 cortex from the auditory cortical fields of ADF, AVF and AAF. Using multi-channel extracellular recording techniques in anesthetized animals, we found that the lateral bank of rostral suprasylvian sulcus (LRSS) revealed a high proportion (46%; 229/495) of neurons that were responsive to both somatosensory and auditory stimuli (i.e., bimodal). This was consistent with the hypothesis that multisensory convergence occurs at the borders of between adjoining representations of different sensory modalities. However, the vast majority (83.4%; 191/229) of bimodal neurons in LRSS failed to demonstrate response enhancement despite the fact that the stimuli were spatially congruent (presented within their respective receptive fields). Of the bimodal neurons that showed enhancement (16.6%; 38/229), they averaged only a 24% response increase. However, in these tests, the temporal relationship between the stimulus onsets was fixed at 25 ms (auditory 25 ms before somatosensory). Therefore, it seemed possible that these stimuli might not have been presented at the temporal interval appropriate to elicit enhancement. Experiments using stimulus pairings at ±100, 50, 25 and 0 ms onset intervals were then presented, but these temporal combinations similarly failed to elicit the expected levels of multisensory enhancement. Instead it was revealed that some bimodal neurons were preferentially activated by somatosensory stimuli (and others by auditory), and that combining these stimuli often generated a response that was quite similar to the dominant, single-modality response. Given this exhaustive temporal analysis, these data suggest that cortical bimodal neurons might not universally generate enhanced responses to combined-modality stimulation.

Proprioceptive mis-estimation of head orientation and the apparent steepness of downhill slopes

Zhi Li, Frank H Durgin

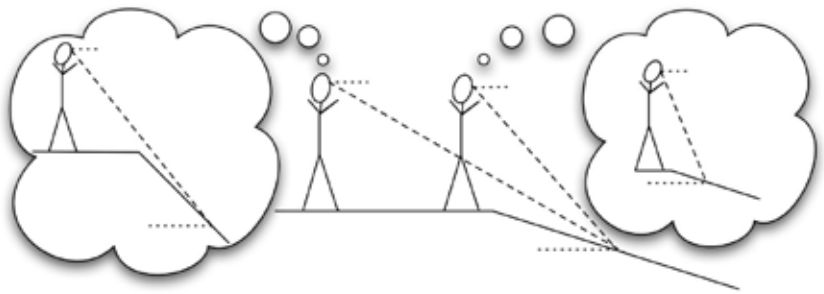
Swarthmore College

Downhill slope perception may depend on combining optical information with proprioception regarding head and gaze orientation. When looking down a hill or sloped surface (see figure), the angle formed between the hill surface and the line of gaze (optical slant) is the difference between the declination of gaze below the horizontal (or pitch) and the declination of the surface from the horizontal (geographical slant). Thus if one steps back from the edge of a hill so that one's incident gaze is nearly parallel with the hill surface, the angle of gaze itself provides an excellent estimate of the slope of the hill. Interestingly, perceived downhill slopes viewed in this way appear much steeper than they are. Importantly, the head itself feels like it is also steeply inclined. One might imagine that the misperception of head orientation (pitch) during hillside viewing was itself somehow due to the misperception of the hill surface. However, blindfolded experimental participants in the laboratory also misperceive their head pitch. When asked to produce elevations or declinations of the head by 10 to 60 degrees, the produced head orientations are about half what they should be: perceived head orientation seems to increase twice as fast as actual head orientation. Downhill slope misperception may be related to proprioceptive errors concerning the pitch of the head and of gaze.

We designed an experiment to compare perceived downhill slope from different vantage points atop a simulated hill. Using an optically-correct immersive virtual reality depicting a virtual environment with rich 3D textures of rocks to specify surface orientations, we simulated realistic downhill slopes from 5 to 34 degrees. Twenty-four observers made verbal slope judgments of these slopes while viewing them from the edge of the slope or from a meter back from the edge.

Perceived optic slant can be inferred from slope judgments under different models of the perception of gaze orientation according to the geometry outlined above. The assumption that perceived optical slant was a continuous function of actual optical slant (using a logarithmic

function) was sufficient to constrain our simple geometric model: The model only fit the judgment data when perceived head/gaze pitch was assumed to be exaggerated by a factor of about 2, consistent with our direct measurements of the gain of head pitch proprioception. Whereas hills appear quite steep when viewed back from the edge, we found that they appeared much shallower – both in virtual reality and in the real world – when viewed from near the edge of the hill. In our model this reflects a logarithmic coding of optical slant in combination with a linear exaggeration of gaze declination. When optical slant is small, the hill appears parallel to misperceived gaze, as shown at the left side of the figure. When optical slant is larger however, the hill surface will appear more frontal to gaze than it is, resulting in the situation depicted on the right side of the figure. This frontal tendency more than makes up for the exaggerated sense of head pitch when looking down on the hill from near the edge. We conclude that perceived downhill slope combines both proprioceptive and visual information.



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Audio-visual interactions in discrimination of intensity changes

I-Fan Lin, Barbara G. Shinn-Cunningham,

Boston University

Many past studies have shown that information in one sensory modality affects perception in another modality. Moreover, the relative influence of one modality on another often reflects the reliability of sensory information. For instance, the auditory system has better temporal resolution than vision. When observers are asked to count the number of light flashes in an audio-visual presentation, the number of sound events dominates perception; however, there is little effect of visual temporal structure on auditory judgments. Here, we investigated whether across-modality interactions on perception stimulus intensity are asymmetric when judging changes in light vs. sound intensity.

Seventeen subjects were presented with paired audio-visual stimuli in a two-interval, forced-choice paradigm. In the auditory intensity discrimination session, observers judged which interval containing the louder sound while trying to ignore the light. In the visual intensity discrimination session, they judged which interval containing the brighter light while trying to ignore the sound. In both sessions, the stimulus in the irrelevant modality could be equal in the two intervals of a trial (neutral), could change in the same way as the attended modality (so that the interval that was louder was also brighter; congruent), or could change in the opposite direction (so that the interval that was louder was dimmer; incongruent).

Results showed that the ability to discriminate changes in intensity of the target modality was affected by the changes in the irrelevant modality, both when listeners judged sound and light intensity. In both cases, listeners were best at identifying the direction of the intensity change in the attended modality in congruent trials, intermediate in neutral trials, and worst in the incongruent trials. These observations show that changes in light intensity influence judgments of changes in sound intensity, and vice versa.

DAY 4 - THURSDAY

Audiovisual interaction: Spatial attention effects and duration illusion

Beatriz R. Sarmiento, Daniel Sanabria Lucena

University of Granada

In this study, we used a variation of the costs and benefits paradigm to investigate the role of endogenous and exogenous spatial attention on crossmodal interactions. Participants had to discriminate between visual stimuli, which were presented alone or in synchrony with auditory stimuli. The duration of both the visual and auditory stimuli was manipulated giving rise to congruent or incongruent trials. Two different tasks were used: 1) Temporal discrimination: Participants discriminated the duration of the visual stimulus while ignoring the duration of the auditory stimulus, 2) Non-temporal discrimination: Participants performed a visual perceptual discrimination task where stimulus duration was irrelevant.

The results showed that the duration of the sound biased the perceived duration of the visual stimulus revealing a novel audiovisual illusion: A long sound made a short visual stimulus be perceived longer and a short sound made a long visual stimuli be perceived shorter. We also present the results of the effect of endogenous and exogenous spatial attention adding new evidence to the hypothesis that multisensory integration depends on spatial attention.

The Semantics of Touch: How People Intuitively Perceive and Interpret Tactile Signals

Huiyang Li, Thomas Ferris, Nadine Sarter

University of Michigan

Vibrotactile signals have the potential to communicate a wide range of information, thus offloading other currently overloaded channels like vision and audition and enhancing the effectiveness and versatility of multimodal interfaces. Most recently, tactons (tactile icons), i.e., abstract structured vibrotactile messages that are analogous to visual icons and auditory earcons, have received considerable attention. To ensure the intuitiveness and robustness of tactons and to reduce the training needs associated with these signals, it is critical to examine how people perceive and interpret tactile signals, to what extent users agree on their interpretation, and to what extent the perceived perceptual and semantic properties of a signal correlate with each other. Very few studies to date have attempted to address these questions. To help fill this gap, a total of 19 participants (UM students) completed a 30-minute session during which they were presented once each with 16 vibrotactile signals in randomized order. These signals were presented via C2 "tactors" (manufactured by Engineering Acoustics, Inc.) and varied along the dimensions of frequency (between 30Hz-350Hz), amplitude (2-4), gain (1-4; with a gain of 4 translating to an approximately 1mm displacement of the skin), and waveform (sinusoidal, heterodyned with low frequency signals or with similar frequency signals, square/pulsing). A reference stimulus with a frequency of 250Hz, a gain of 3 and a duration of 1000ms preceded each experimental stimulus. The participants were asked to describe the tactile signals in terms of 1) the sensation they triggered, and 2) their assumed meaning. They were asked to provide at least one adjective for each of these two dimensions. The analysis of the resulting data indicates that the adjectives used to describe the sensation relate to the following six dimensions: strength, time, texture, salience, dynamics and annoyance. Each dimension, in turn, consists of several sub-dimensions (e.g., sharpness, texture, softness, and roughness for the dimension of texture). The adjectives that were used to describe the assumed meaning of each signal fall into six categories as well: excitement, urgency, alarm, information, pleasantness and strength.

Again, most of these categories include several sub-dimensions, such as importance, urgency, and danger for the category of urgency. The six pulsing and heterodyned signals of similar frequencies were perceived by 27-43% of the participants as relating to the temporal dimension of 'dynamics'. Between 14-29% of subjects interpreted them as urgent or alarming. The level of perceived urgency increased with the difference between the two frequencies of the heterodyned signal. High frequency and high gain signals (350 Hz or a gain of 4) were most often perceived as relating to strength and urgency. Signals with a high frequency were also associated with the emotive quality of 'unpleasant'. As many as 57.6% of the participants described stimuli with both a frequency of 350 Hz and a gain of 4 as urgent; 35.7% of the subjects interpreted them as alarming, and 21.4% referred it to them as being uncomfortable. In contrast, low frequency tactons (below 150 Hz) tended to be interpreted as weak, soft, and slow, as well as pleasant or comfortable. Finally, more than 40% of the participants describe the two signals with a gain lower than the reference signal as soft, weak or unnoticeable. Overall, the findings from this study reveal a number of rather robust natural mappings between properties of tactile stimuli and their perceived meaning. They help designers of tactile and multimodal interfaces by taking a first step towards creating a tactile vocabulary and by identifying stimuli that should be avoided because of large interindividual differences in interpretation.

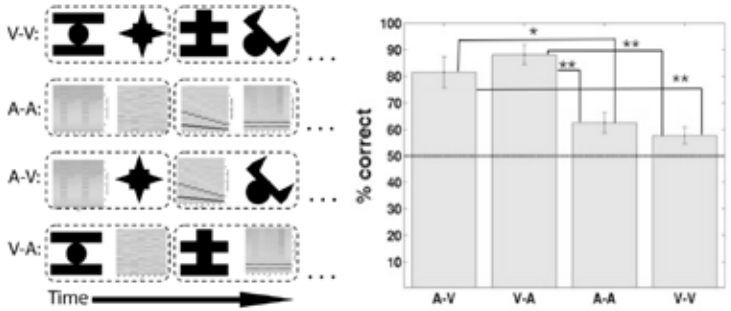
Statistical learning of crossmodal associations is better than unisensory associations

Robyn Sun Kim [1], Aaron Seitz [2], Ladan Shams [1]

[1]UCLA, [2]UC Riverside

Background: The human brain is constantly engaged in learning new regularities and associations in the sensory environment. Statistical Learning studies have shown that this type of learning can even occur passively and in the absence of a task. We have recently demonstrated that learning of audio-visual sequences can occur in parallel and independently of unisensory auditory and unisensory visual learning (Seitz, Kim et al. 2007). Here we asked whether learning of unisensory and cross modal associations are equally efficient or if there is a difference between these types of learning. On the one hand, there is more connectivity within sensory regions, and therefore, establishing associations between tokens within the same modality may be more efficient. On the other hand, the noise processes that corrupt signals within the same sensory modality tend to be dependent, and these correlations due to noise may mask the meaningful correlations and make learning of within-modality associations more difficult. Purpose: In the current experiment, we directly compared learning of auditory-visual and visual-auditory sequential pairs with learning of visual-visual and auditory-auditory sequential pairs. Method: 36 naïve subjects were randomly assigned to one of four groups (A-V, V-A, A-A, or V-V). Each participant was first passively exposed to a stream of stimuli (see Figure, left panel). Unbeknownst to the subjects, the stream consisted of randomly ordered repetitions of four base-pair sequences. For the A-V, V-A, A-A, and V-V groups, base pairs consisted of a sound followed by an image (A-V), an image followed by a sound (V-A), a sound followed by another sound (A-A), or an image followed by another image (V-V), respectively. At the time of exposure, subjects were asked to observe the stimuli, and were not informed of the subsequent test. After exposure, participants were tested in a two-interval forced choice task in which they indicated which of two sequential stimulus pairs seemed more familiar. Results: A-V, V-A and A-A groups performed significantly above chance in the familiarity test, and the V-V group was marginally close to significance (p=.055). However, both crossmodal groups showed significantly better performance than both unisensory

groups (see Figure, right panel). These data indicate that, indeed, auditory-visual sequential learning is superior to unisensory visual and unisensory auditory sequential learning.



Figure, left: Examples of stimulus streams for V-V, A-A, A-V, and V-A groups. Auditory stimuli are represented by spectrograms. Dashed rectangles indicate base pairs. Figure, right: Results of familiarity test.

Multiple Modes of Perceptual Training Induce a Narrowing in the Multisensory Temporal Binding Window

Albert R. Powers, Andrea R. Hillock, Mark T. Wallace

Vanderbilt University

The brain's ability to bind incoming auditory and visual stimuli depends critically on the temporal structure of this information. Specifically, there exists a temporal window of audiovisual integration within which stimuli are highly likely to be bound together and perceived as part of the same environmental event. Several studies have described the size and malleability of this window in adults, and we have shown in recent work that the size of the multisensory temporal binding window can be narrowed with the use of a perceptual training paradigm. However, the specific mechanisms underlying these changes were not clear, and to rule out the possibility that they could be the result of cognitive biases, a new, two-interval forced choice (2IFC) paradigm was undertaken during which participants were instructed to identify a simultaneously-presented audiovisual pair presented within one of two intervals, and in which the stimulus onset asynchrony between the visual and auditory stimuli in the other interval was variable. While the new training paradigm also resulted in a window narrowing and generalization pattern similar to that seen using the two alternative approach, the 2IFC paradigm resulted in a larger overall decline in window size that took place over a slower time course. These findings indicate that these different methods of multisensory perceptual training both result in substantial alterations in the circuits underlying the perception of audiovisual simultaneity, a hypothesis supported by preliminary imaging data showing blood-oxygen-level dependent (BOLD) changes in canonical multisensory cortical regions after perceptual training. Taken together, these results suggest a high degree of flexibility in multisensory temporal processing and have important implications for interventional strategies that may be used to ameliorate clinical conditions (e.g., autism, dyslexia) in which multisensory temporal function may be impaired.

The way of touch: the important factor for visual adjustment of haptic size judgements

Kensuke Oshima, Shigeru Ichihara

Tokyo Metropolitan University

Lederman & Klatky (1987) showed that people selected the way of touch properly for the task. So the way of touch is important for knowing the environments. But previous studies of interaction between vision and touch hardly regarded the way of touch. We think the way of touch is one of the important factors for the interaction between vision and touch. We examined visual adjustement of haptic size judgements and compared different ways of touch. Participants were in an experimentally created intersensory size conflict between vision and touch. In experimental conditions the participant's task was haptic size judgements of the squares with their three fingers when they simultaneously "grasped" or "grasped and traced" and looked the squares. When participants were looking smaller square than physical size of the square, in experimental conditions they selected smaller square than haptic control condition. Visual adjustment of haptic size judgements were comfirmed. In "grasp" condition visual adjustment of touch was greater than "grasp and trace" condition. We suggest that the way of touch affects visual adjustments of touch and is the considerable factor for interaction between vision and touch.

Interactions between tactile and auditory signals in roughness perception: A human psychophysical study

Manuel Gomez-Ramirez

Johns Hopkins University

Previous studies have shown that vibratory stimuli can convey texture information in both the tactile and auditory systems. It has also been shown that auditory stimuli can influence tactile texture perception. However, how the auditory and tactile systems process the vibratory stimuli as textures is unclear. In this study, we examined, 1) the similarities between tactile and auditory roughness perception using the same vibratory stimuli, and 2) how unattended auditory stimuli influence roughness perception of tactile stimuli. We first obtained the texture-based vibratory stimuli by recording through a stationary probe placed against moving textures. These stimuli were then used in three experimental conditions. In condition 1 (Tactile-only), participants were presented only with vibrotactile stimuli. In condition 2 (Auditory-only), participants were presented with auditory stimuli alone. In condition 3 (Audio-Tactile), participants were presented with combined auditory and tactile stimuli. Tactile-only and Audio-Tactile conditions required participants to rate the subjective-magnitude estimates of roughness of the tactile stimuli, while the auditory-only condition required participants to rate the perceived auditory roughness. We found a correlation between tactile and auditory ratings of roughness. In addition, we found that auditory stimuli increased perceived tactile roughness ratings. The correlation between perceived tactile roughness and perceived auditory roughness indicates that these sensory systems may use similar but not identical texture information processing mechanisms.

Lip-reading aids word recognition most in moderate noise: a Bayesian explanation using high-dimensional feature space

Xiang Zhou [1], Wei Ji Ma [2], Lars A Ross [1], John J Foxe [1], Lucas C Parra [1]

[1]City College of New York, [2]Baylor College of Medicine

Watching a speaker's facial movements can dramatically enhance our ability to comprehend words, especially in noisy environments. From a general doctrine of combining information from different sensory modalities (the principle of inverse effectiveness), one would expect that the visual signals would be most effective at the highest levels of auditory noise. In contrast, we find, in accord with a recent paper, that visual information improves performance more at intermediate levels of auditory noise than at the highest levels, and we show that a novel visual stimulus containing only temporal information does the same. We present a Bayesian model of optimal cue integration that can explain these conflicts. In this model, words are regarded as points in a multidimensional space and word recognition is a probabilistic inference process. When the dimensionality of the feature space is low, the Bayesian model predicts inverse effectiveness; when the dimensionality is high, the enhancement is maximal at intermediate auditory noise levels. When the auditory and visual stimuli differ slightly in high noise, the model makes a counterintuitive prediction: as sound quality increases, the proportion of reported words corresponding to the visual stimulus should first increase and then decrease. We confirm this prediction in a behavioral experiment. We conclude that auditory-visual speech perception obeys the same notion of optimality previously observed only for simple multisensory stimuli.

The effect of binocular and monocular viewing on sound localization

Adria E. N. Hoover, Laurence R. Harris, Jennifer K. E. Steeves

Centre for Vision Research, York University, Toronto

Problem
Does temporary loss of binocularity and asymmetrical cortical input in normally sighted individuals have immediate effects on audition? Research suggests that early-blind individuals can localize sound better than sighted controls (Lessard et al., 1998 Nature 395: 278). This may reflect recruiting of visual cortex for spatial auditory processing (Voss et al. 2008 Neuroimage 40: 746). Losing one eye deprives the contralateral hemisphere of crossed visual input and the ipsilateral cortex of uncrossed input and also eliminates binocular input. As a first step to investigating the possible consequences of this loss of binocularity and remaining asymmetrical cortical input on spatial auditory perception we measured the effect of covering one or both eyes in normally sighted individuals on sound localization.

Methods
Subjects were asked to judge the location of double bursts (each one 30ms) of white noise played through tweeters spaced horizontally in a semicircular array in front of the subject. The speakers were hidden from view by a sound-transparent cloth. Subjects listened with (1) both eyes open in the light, viewing a fixation point straight ahead, (2) with either eye patched while viewing the fixation point and (3) with both eyes closed or in the dark. Subjects reported the perceived location of the sound relative to a visual scale. Each speaker location was tested several times. Conditions were run successively in counterbalanced order.

Results
The perceived location of sounds with eyes closed was biased toward the straight ahead direction by an amount proportional to the speaker's eccentricity. This bias increased when the eyes were open. When viewing monocularly, the bias toward straight ahead was even larger but only in the occluded field.

Discussion
Changes in visual input have immediate effects on the accuracy with which sounds can be localized. Paradoxically vision does not help but rather increases error. Monocular viewing is associated with the greatest bias toward the straight ahead but only within the occluded field. This finding is discussed in terms of cortical contributions to sound localization and the possible effects of losing one eye.

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Unisensory temporal performance is predictive of the size of the temporal window of multisensory integration

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A great deal of recent research had focused on the temporal window of multisensory integration, the period of time within which multisensory stimuli are likely to be bound into a unitary construct. In contrast, few studies have attempted to relate features of unisensory temporal performance to measures of multisensory temporal processing. Studies using animal models have shown that the temporal dynamics of neuronal responses to unisensory stimuli are an important determinant of the temporal pattern of multisensory response enhancements and depressions. However, no study has demonstrated a similar relationship at the perceptual level. In the current study we attempted to accomplish this by measuring temporal thresholds on auditory and visual temporal order judgment (TOJ) tasks and relating these thresholds to the temporal window of multisensory integration as defined using two tasks - a multisensory TOJ (mTOJ) task as well as a temporally-dependent multisensory illusion (i.e., flash-beep (FB)). We found that higher visual TOJ thresholds were associated with larger temporal windows in both the multisensory TOJ ($r = .663$, $p<.004$) and flash-beep ($r = .418$, $p<.05$) tasks. In addition, higher visual TOJ thresholds were associated with increased reports of the flash-beep illusion ($r = .466$, $p<.02$). In contrast, auditory TOJ thresholds did not significantly correlate with window size on either multisensory task (mTOJ ($r = .397$, $p = .115$); FB ($r = .235$, $p = .292$)), or with perceptual reports on the illusory task ($r = .159$, $p = .447$). These results illustrate a close relationship between unisensory temporal processing and multisensory temporal processing. Future research will focus on determining the task specificity of these effects, and on better characterizing the temporal dynamics and interrelationships between unisensory and multisensory performance and perception.

Body orientation and perspective influence conscious monitoring of locomotion in a virtual reality setting

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Recently we reported data on motor contributions to the bodily awareness of the entire body (agency) during locomotion in a virtual reality setting (Kannape et al. IMRF 2008). In this first study, we asked 9 participants to walk towards 4 different target positions while their body movements were tracked via optical motion capture. Movements were mapped onto a virtual body and played back, in real-time, on a projection screen. The body movement and position of the virtual character could systematically be deviated from the participants' movements by ±5°, ±10°, ±15°, or ±30°. Motor Performance (MP) and Motor Awareness (MA) were measured. Results showed that participants are unaware of angular biases of ~10° despite participants' motor behaviour (significantly deviated walking paths in the direction opposite to the deviation; $p<0.001$).

In the current study (N=14) we investigated the influence of a) the virtual body's orientation and b) its walking direction. We further analysed the relationship between MA and MP, with the Motor Awareness Index (MAI), which describes the likelihood of errors in MA with respect to MP. We found a significant orientation x direction interaction for MP, $p=0.016$ due to best MP when the virtual body's orientation and walking direction matched those of the participant. MA (point of subjective ambiguity) was higher than in study 1 (13.8°±0.83°), but did not differ across the experimental conditions (all $p>0.18$). However, analysis of the MAI revealed that participants were more likely to make MA errors in the inverted conditions ($p=0.016$).

Our findings show that humans track the position and locomotion of their body (and thus the experienced centre of conscious awareness) with a surprisingly low accuracy within a peripersonal space of ~13.8°. This incorrect awareness during goal-directed locomotion and navigation - found under the present experimental conditions - suggests that the generation of full-body locomotion and the building of a conscious experience of it are distinct brain processes.

fMRI of a visual-haptic ambiguous rotating sphere

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The illusion of a transparent three-dimensional rotating sphere is elicited by a two-dimensional cluster of moving dots. The direction of motion is ambiguous, producing alternating perceptual states. To disambiguate the rotation we presented a haptic rotating sphere additionally to the visual one. The axial orientations of the visual and the haptic sphere were congruent for disambiguation and incongruent for synchronous bimodal stimulation with incongruent direction information. Thereby physical incongruence and perceptual incongruence– the haptic direction of rotation is perceived as being opposite to the visual also the rotation axis is the same –could be examined.

Congruent visual-haptic stimulation resulted in an increased activation of primary sensory areas compared to incongruent visual-haptic stimulation. Activation was also found in higher heteromodal cortical areas such as the superior temporal sulcus (STS), the temporoparietal area (Tpt) and the human motion complex (hMT+). In conclusion, congruent crossmodal stimulation enhanced brain activity in areas attributed to multisensory integration, even though this effect did not emerge as clear in the behavioral data.

Auditory input modulates activity in primary somatosensory cortex

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Nathan Kline Institute

There is growing evidence that primary sensory cortices receive inputs from multiple modalities and activity in these areas can be modulated in a variety of ways by non-primary activity. Recent data show that somatosensory input amplifies auditory responses by resetting ongoing neural oscillations in superficial layers of A1 to a high-excitability phase. Our objective was to examine the inverse of this effect in primary somatosensory cortex, and to describe the physiology of somatosensory-auditory interaction mechanisms across area 3B's cortical laminae. Our data show the presence of nominal interactions in superficial cortical layers with relatively high levels of somatosensory stimulation. According to the principle of inverse effectiveness, and the previous pattern reported in auditory cortex, we predict that these interactions should be stronger with reduced intensity, as multisensory interactions are stronger when unisensory stimulation evokes weaker responses. We are currently looking at auditory-somatosensory interactions at reduced somatosensory intensities. These putative findings combined with our initial results show that primary somatosensory cortex operatively integrates auditory input and that neuronal oscillations play a key role in its multi-modal operations.

Highly transient neuroplasticity following one session of learning to use a sensory substitution device: an fMRI study

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Sensory substitution devices (SSDs) transform visual information into auditory or tactile input non-invasively, and enable the blind to "see" using their other senses. Recent studies have shown that shape recognition using the vOICe, a visual-to-auditory SSD, activates the lateral occipital cortex (LOC), the visual object related area, after prolonged use of the device (i.e. following weeks of training). One remaining question is whether such plastic changes in brain areas (especially visual areas) can occur much more rapidly? Occipital cortex undergoes dramatic cross-modal plasticity in the blind. This could reflect connectivity and processing, which exist also in sighted (but are inhibited to some extent by visual input), or massive reorganization and growth of new connections due to prolonged blindness. Here we studied neuroplasticity in time scales that do not enable growth of new connections. Using fMRI, we studied blind and sighted individuals to define the neural correlates, brain dynamics and brain plasticity of learning to use the vOICe SSD. Naïve subjects were scanned during a SSD object recognition task before they were given an explanation of the visual-to-auditory transformation algorithm, and then, at the same day, following a one-hour training session in which the vOICe principles were explained and practiced. Following a one-hour shape-recognition training session, activation of the LOC increased significantly, in both sighted and congenitally blind subjects. These results show that very short training of the use of SSDs results in a task-specific rapid effect of neuroplasticity in the object related visual cortex. These results suggest that visual cortex plasticity can be seen in extremely short time scales, in both sighted and blind individuals, giving high hopes for the possibility of quick learning and useful implementation of sensory substitution in the blind. More importantly, the speed of these functional changes makes the establishment of new connections highly improbable. Thus, the rapid changes in existing connectivity might be an important mechanism for such rapid neuroplasticity in the adult brain.

You see? You don't feel: Spatially Modulated Visuo-tactile Extinction in Healthy Subjects

Claudio Brozzoli, Romeo Salemme, Alessandro Farnè

INSERM U864 "Espace et Action"

Right brain-damaged (RBD) patients may present a deficit known as 'extinction': they fail to report a stimulation in the contralesional hemispace when cuncurrently delivered with an ipsilesional stimulus. Cross-modal extinction has been documented between different sensory modalities, such as touch and vision. We recently reported an extinction-like phenomenon in healthy people, in the tactile modality. Here we report cross-modal extinction phenomenon in normal subjects, between vision and touch. Subjects were presented with visual stimulations (30 ms) on a computer monitor, and touches (electro-cutaneous, 100 μs) on the index finger of the left or right hand placed just below the monitor. Visual stimuli could be either near (left/right bottom corner) or far from (left/right upper corner) each hand. Visual and tactile stimulations could be delivered singlhy or simultaneously combined on both sides (a visual stimulaiton on the right and a touch on the left, or viceversa). Subjects were asked to discriminate stimulations (left, right or both), irrespective of the sensory modality, by making a saccadic eye-movement (to a leftward, rightward, or upperward square from the fixation point), recorded by an eyetracking system. Results showed that subjects perceived tactile stimulation better when delivered alone than simultaneously with a visual stimulation on the contralateral hemispace, particularly when it was presented close to the hand. Subjects' performance on unilateral touches were less affected by visual stimuli when presented far from the hands. These results suggest that cross-modal visuo-tacile extinction-like phenomena are physiologically present in the healthy brain. Pathological extinction could thus be an exaggerated form of normal, spatially modulated competition between inputs from different sensory modalities.

Low but accurate detection rates for small degrees of Audiovisual Asynchrony

Durk Talsma

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It is a well known phenomenon that near simultaneously presented auditory and visual stimuli are being perceived as one multisensory object. Multisensory integration can take place, even when there is a considerable stimulus onset asynchrony (SOA) between the visual and auditory inputs (up to 250 ms), suggesting that auditory and visual stimuli are internally realighened. In the present study we sought to address the question of not only at which SOAs participants began to detect these offsets, but also whether they would be able to tell whether the auditory stimulus preceded or succeeded the visual stimulus. Auditory and visual stimuli were presented in pairs, with a randomly varying SOA of -450 (auditory stimulus preceding the visual one) to +450 ms (auditory stimulus succeeding the visual one). Participants were instructed to respond only when they believed there was an actual offset between the stimuli, and if so, make a two-choice response to indicate whether the visual stimulus was earlier or later. All stimuli were grouped in 7 bins, depending on SOA. Results show that detection rate increased with SOA, generally being higher when the auditory stimulus preceded the visual one. Interestingly, even when detection rate was low, for the smaller SOAs, detection accuracy remained relatively constant across all SOA conditions, suggesting that observers still have access to the underlying temporal structure, even at small SOAs.

Reliability-based cue re-weighting in rhesus monkeys: behavior and neural correlates

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The information received through our senses is inherently probabilistic, and one of the main tasks faced by the brain is to construct an accurate representation of the world in spite of this uncertainty. This problem is particularly relevant when considering the integration of multiple sensory cues, since the uncertainty associated with each cue can vary rapidly and unpredictably. Recent psychophysical studies have shown that human observers combine cues by weighting them in proportion to their reliability, consistent with statistically optimal schemes derived from Bayesian probability theory. Remarkably, because cue reliability was varied randomly across trials, the setting of the weights must occur on the time scale of a single stimulus presentation.

The neural basis of cue re-weighting remains unknown, in part due to the lack of a suitable animal model system for simultaneous behavioral and neurophysiological measurements in the context of cue integration. We have developed a psychophysical paradigm in monkeys in which they are trained to report their self-motion direction (heading), using visual cues (optic flow), vestibular cues (inertial motion), or a combination of both. On a subset of trials, a small conflict angle was introduced between the visual and vestibular heading trajectories, and the relative reliability of the cues was varied by interleaving different levels of visual motion coherence.

We found that monkeys can dynamically re-weight cues according to their reliability, the first such demonstration in a species other than humans. During the task, we recorded single units from area MSTd, a region strongly implicated in the processing of visual and vestibular self-motion cues. We used ROC analysis to quantify the behavior of an ideal observer performing the same task as the animal but using only the firing rate of the neuron. Preliminary results suggest that MSTd neurons exhibit dynamic cue re-weighting with changes in reliability, analogous to the monkeys' behavior. To our knowledge, this result provides the first direct evidence of a neural implementation of Bayesian inference in multisensory processing.

Tactile Influence Upon Visual Perception of the Ambiguous Motion Quartets

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In perceptual rivalry an observer is presented with an ambiguous stimulus that can generate two mutually exclusive, alternating perceptions. The bistable apparent motion quartet, where two stimuli from diagonally opposite corners of a square are presented at the same time in alternation with the other diagonals of the square, has been shown to induce perceptual rivalry in both the visual and tactile domains. We explored the cross-modal effects of a stable, unambiguous tactile apparent motion stimulus on a bistable visual apparent motion quartet during both an event-related and a continuous report task, using spatially coinciding visual and tactile stimuli attached to the 2nd and 4th digit of subjects' hand. In the event related task, subjects were presented with a sequence of two 500ms visual motion quartets at 600ms inter-stimulus interval and were asked to report the perceived sequence of the two possible percepts (horizontal or vertical motion). In the continuous report task, subjects were presented with 3 minute visual motion quartets (no ISI) and asked to continuously press a response button corresponding to their current percept. During both tasks, subjects were also presented with unambiguous tactile motion stimuli, either simultaneously or preceding the visual stimulus by 40 ms, in order to test potential cross-sensory biasing effects. No significant cross-modal influence of the tactile stimulus was observed in the event-related task. However, in the continuous report task, tactile stimulation in the horizontal direction significantly increased the total time subjects spent perceiving the ambiguous visual stimulus as a horizontal motion stimulus. Furthermore, results showed a significant bias in the perceptual reversal rate of the bistable visual stimulus towards the horizontal direction of the unambiguous tactile motion stimulus. These data show that the perception of a bistable motion stimulus in one modality (visual) can be positively biased by concurrent cross-sensory input (tactile), demonstrating multisensory links during perceptual rivalry.

Stimulus duration has influence on the perceived simultaneity in audiovisual temporal order judgment

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Purpose: Temporal integration of stimuli of different sensory modalities plays a crucial role in multisensory processing. Previous studies using temporal-order judgment determining the point of subjective simultaneity (PSS) with multisensory cues yielded conflicting results about modality-specific delays. While it is known that the relative stimulus intensities of stimuli from different sensory modalities affect their perceived temporal order, we have hypothesized that some of these discrepancies might be explained by a previously overlooked confounding factor, namely the duration of the multisensory stimulus. Methods: We have studied the influence of both factors on the PSS in a spatial-audiovisual temporal-order task using the method of constant stimuli and participants were asked which onset of an event appeared first ("left" or "right").

Results: In addition to confirming previous results on the role of stimulus intensity, we report that varying the temporal duration of an AV stimulus pair stimulus also affected the perceived temporal order of the auditory and visual stimulus components. While individual PSS values varied from negative to positive values across participants, we found a systematic shift of PSS values towards an attractor value with increasing stimulus duration. Conclusion: This effect was manifest in a shift of a subject's individual PSS value with increasing stimulus duration towards an attractor value that was valid for the entire population. This dependence is indicative of a mechanism which stabilizes perceived stimulus asynchronies and might serve as a mechanism which exploits stimulus duration to compensate individually present attentional imbalances between sensory modalities. Thus, increasing stimulus duration, at least in the range tested, might facilitate crossmodal binding processes. Moreover, we provide evidence that the duration effect helps resolving conflicting results in previous studies on audiovisual temporal-order judgment.

Visuo-motor resonance in older adults

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Recent evidence has shown that visual and auditory inputs related to meaningful actions (e.g. grasping a peanut or ripping paper) can activate the motor system and specifically, mirror neurons in the cortex (Fogassi & Gallese, 2004; Rizzolatti & Craighero, 2004). This mechanism of 'motor resonance' is thought to be the neural underpinning of a congruency effect found at the behavioural level with a visuomotor priming paradigm (e.g. Bruzzo, Borghi & Ghirlanda, 2008). To our knowledge no study has investigated visuo-motor resonance in older adults, i.e. in a population subjected to the deterioration of perceptual and motor skills.

In the present study older and younger adults were asked to judge the weight ('heavy' or 'light') of images of objects. The pictures were preceded by primes depicting a generic grasping action or no action (arm with hand in fist position). We hypothesised that if motor resonance occurs in weight judgement, i.e. in a cognitive judgment not directly implying action upon the object, participants performance should be modulated by the type of prime. We further hypothesised that the motor resonance mechanism would interact with the action required to respond, i.e. right handed participants should be faster in responding 'heavy' to heavy objects with the right hand than with the left hand. In addition we manipulated the interplay between the characteristics of the agent in the prime and the participant (i.e. male vs. female; older vs. younger). Hence we further hypothesised a modulation of the priming effect when the participant and the agent shared the same sex and/or age (Calvo-Merino, Glaser, Grèzes, Passingham, Haggard, 2005). Our results show that the kind of prime (action or no action) modulates participants' performance when the characteristics of the agent hand in the prime and those of the participant are shared. The mapping between the hand used to respond to the weight of the object also affects performance. These findings have important implications for the understanding of multisensory perception for action.

Cognitive load during training facilitates expert skilled performance in a complex spatio-temporal domain

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The ultimate aim of military fast jet flying training is to produce operational military pilots with expertise in the air combat domain. The higher-order cognitive skills of particular concern in this study are 4D spatio-temporal skills, which develop incrementally through training and experience. The notion of 2D, 3D and 4D spatio-temporal skills embodies a number of layers of meaning in the aviation domain.

Briefly, 2D space can be thought of as a planar view of space within an altitude buffer, which is referenced to the ground and the horizon. 3D space includes altitude as a dimension providing potential energy both in the physical sense and in the aerobatic manoeuvring sense. 4D space includes a temporal factor e.g., as would be required to intercept other dynamic entities. Trainee fighter pilots progress through an increasingly complex spatio-temporal domain during training. The additional cognitive load inherent in each new training phase can lead to a breakdown in airmanship (i.e., performing previously learned procedures out of sequence, committing unsafe acts, suffering information overload, and failing to prioritise appropriately). This paper examines the application of contextually- relevant cognitive load offered by new sensor and simulated threat technologies during training to consolidate 4D spatio-temporal skills and decision-making at each training level. This will ensure that there is spare cognitive capacity to proceed to the next training phase, facilitating the development of airmanship within the compressed timeline of the spatially complex air combat environment.

Haptic discrimination in blind and low-vision children

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Purpose of the study:
Our recent results suggest that the development of multimodal integration of spatial information occurs late in childhood, around 8-10 years of age. Before integration is observed, either the haptic or visual system dominates, depending on the task: haptic for size and vision for orientation. If our suggestion that dominance is a side effect of sensory calibration, it should have direct consequences on children born without the possibility to use one sense to calibrate the other. For example, children without hands may show reduced precision in visual size judgments, as vision has not been calibrated against the more robust haptic sense; and conversely, children born blind or severely visually impaired should show reduced acuity for haptic orientation judgments.

Methods:
We measured haptic discrimination thresholds for size and orientation discrimination in young (5-12 year-old) low-vision and blind children (with vision below 1/10), using the technique of Gori et.al. (Curr. Biol., 2008). For the size task children were presented successively with two plastic blocks and asked to judge haptically in 2IFC which was the taller (guessing if unsure). One stimulus (randomly first or second) was 55 mm high, the other of variable height between 48 and 62 mm. The proportion of trials where the probe was judged taller than the standard was computed for each probe height to produce psychometric functions, well fit by cumulative Gaussian functions (yielding PSE and SD). For the orientation task the procedure was similar to the previous one with the subject reporting haptically in 2IFC in which presentation the slope of the bar was steeper.

Results:
For size discriminations, all subjects were very similar to the average thresholds for normally-sighted age-matched children. But for the orientation discrimination, all were far worse than normally sighted

children: with thresholds of over 45 degrees. They could barely discriminate vertical from horizontal, and were very reluctant to do the task.

Conclusion:
While this does not prove our theory about calibration, it is certainly consistent: if the haptic sense of orientation has never been calibrated against the more robust visual sense it does not develop the precision that normally sighted children have.

Multisensory influence on the perception of foreign accented speech

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For native perceivers, seeing a native talker's face can improve the intelligibility of acoustic speech presented in noise. For this perceiver population, it is also known that the intelligibility of foreign accented English, spoken by native talkers of Mandarin Chinese, is more susceptible to the effects of noise compared to the speech of native talkers (Rogers et al, 2004). The current experiment was designed to investigate the influence of seeing a non-native talker's face on the intelligibility of foreign accented speech presented in noise. Ten talkers (nine non-native and one native) were audio and video recorded producing 155 sentences each. Talker specific speech shaped noise was mixed with the audio of the sentences. The signal-to-noise ratio was set for each talker based on preliminary testing. Eighty-one native perceivers of English (nine per non-native talker) responded to 20 sentences spoken by the native talker and 28 by a non-native talker in each presentation condition (audio-alone, visual-alone, audiovisual). Open set identification responses were scored as percent words correct for each condition and talker. Preliminary analyses demonstrate that seeing the non-native talker increases intelligibility of speech presented in noise. However, the magnitude of the audiovisual gain is reduced in comparison to the gain observed with the native talker. Results will be discussed in terms of potential sources of audiovisual gain. These sources are hypothesized to be differentially sensitive to the influences of non-native speech. [Work supported in part by NIH/NIDCD DC04856 and the University of Kansas, UGRA].

Reference:
Rogers, C. L., Dalby, J., & Nishi, K. (2004). Effects of noise and proficiency on intelligibility of Chinese-accented English. Language and Speech, 47(Pt 2), 139-154.

When right feels left: referral of touch and ownership between the hands

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Feeling touch on a body part is paradigmatically considered to require stimulation of tactile afferents from the body part in question, at least in healthy non-synaesthetic individuals. In contrast to this view, we report a perceptual illusion where people experience "phantom touches" on a right rubber hand when they see it brushed simultaneously with their left hand. Such illusory duplication and transfer of touch from the left to the right hand was only elicited when a homologous pair of hands was brushed in synchrony for an extended period of time. This stimulation caused 16 out of 30 participants to perceive the right rubber hand as their own and to sense two distinct touches – one located on the right rubber hand and the other on their left (stimulated) hand. We found a significant correlation between experiencing the duplication of touch and the feeling ownership of the rubber hand ($N = 30$, $p = 0.021$, two-tailed Pearson correlation; $r = .418$). This effect was supported by behavioral data associated with misreaching in a pointing task when asked to localize the position of the participant's own right hand. There was a significant reaching error towards the right rubber hand when it was brushed in synchrony with the left real hand as compared to the asynchronous mode of brushing which was the control condition ($N = 14$, $p = .012$, two-tailed t-test). Physiological evidence obtained by skin conductance responses when threatening the model hand revealed that people displayed greater emotional responses when we stabbed the rubber hand with the needle after the illusion condition than they did under two appropriate control conditions ($N = 14$, $p = 0.028$, $F = 4.138$, $df = 2$, one-way repeated measures ANOVA). Our findings suggest that visual information augments subthreshold somatosensory responses in the ipsilateral hemisphere, thus producing a tactile experience from the non-stimulated body part. These findings are of fundamental importance because they reveal how multisensory interactions between the hands cause qualitative changes in unimodal tactile perception, and that this has a direct consequence for how we come to experience limbs as part of our own body. Our finding could have a bearing on applied neuroscience, as tactile stimulation to an intact hand in amputees might support the ownership and usage of prosthetic limbs. Similarly, research on stroke rehabilitation should examine the possibility that physiotherapy of a hemiplegic limb might be facilitated by concurrent tactile stimulation of the contralateral limb.

10th International Multisensory Research Forum

DAY 4 - THURSDAY

Accuracy and Precision of Auditory-Visual Localization in the Two-Dimensional Frontal Field: A Test of the Modality Precision Model

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In recent studies, bimodal Visual-Auditory (VA) spatial localization precision as shown to exceed those of the most precise unimodal condition i.e. vision, in accordance with Bayesian integration models such as the Maximum Likelihood Estimate. The novelty of the present study is:

a)To provide for the first time two-dimensional data about bimodal AV integration, for which results suggest the need for multidimensional data analysis (and potentially vectorial) to account for the non-independency of the responses along the two Cartesian dimensions.

b)To take into account the idiosyncratic differences in precision between A and V as a function of Eccentricity and Direction to predict accuracy assuming validity of the Modality precision (MP) model

Results confirmed near optimal integration, localization precision for the AV targets being greater than that of the more precise modality V, while accuracy for the bimodal stimulus tended to be a compromise between the values of individual modalities in favor of vision. The lack of complete integration is discussed in terms of methodological reduction.

Hemifield Asymmetry in the Integration of Exogenous Auditory and Visual Cues in the Capture of Visuospatial Attention in Visual Line Bisection

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Purpose: Neurologically normal observers misperceive the midpoint of horizontal lines as systematically leftward of veridical center, a phenomenon known as pseudoneglect (PN). However, a rightward bias characterizes the perceived midpoint (PSE) of horizontal spatial intervals defined auditorily. Lateral visual cues significantly bias PSE. Using a tachistoscopic visual line bisection (LB) paradigm we assess: 1) whether exogenous lateral auditory cues can bias PSE; and 2) the manner in which auditory (A) and visual (V) cues combine to jointly influence PSE. Methods: Forty-six dextral subjects completed a tachistoscopic LB task. In addition to a no-cue condition, subjects made LB judgments where V and A cues were delivered as unisensory stimuli, and in multisensory combinations, to the right (R) and left (L) line endpoints. Conditions were randomly interleaved. Multisensory cue combinations were spatially congruent (VRAR, VLAL) or discordant (VLAR, VRAL). Results: Table 1 reports mean PSE in degrees visual angle relative to veridical line midpoint for all conditions. There was a significant tonic leftward bias in PSE (PN). Lateral cues influenced PSE such that L cues induced greater leftward bias than R cues. Leftward bias was significantly greater for V cues than for A cues overall. Leftward bias was strongest for VL cues and weakest for VR cues. Table 2 discloses the weights assigned to PSE values in the unisensory A (WA) and V (WV) conditions which optimally predicted PSE values obtained in the multisensory AV conditions. There is a significant hemifield asymmetry in the weights assigned to A and V cues, where VL cues are more heavily weighted than AL or AR cues, but VR cues are equally weighted with AL or AR cues. Conclusions: We confirm a tonic leftward bias in LB PSE. VL cues induce a large leftward shift in PSE and are significantly stronger than A cues, whereas VR cues are equipotent with A cues. These results are consistent with a prepotent vector of visuospatial attention to left hemispace, and a prepotent vector of audiospatial attention to right hemispace, and imply the existence of separate attentional networks for A and V stimuli. Since

the weights for unisensory A and V cues were optimized by least-squares regression to fit PSEs in the AV conditions without constraint, it is especially noteworthy that their sums in each AV condition are nonsignificantly different from unity. This result is consistent with Bayesian cue combination. Bayesian combination implies that some response parameter to exogenous hemispatial A and V cues possesses variances which are inversely proportional to these empirically derived weights. This parameter is yet to be determined; a likely candidate is cue localizability.

Sight, sound and touch less bound: a behavioral and ERP investigation of multisensory integration deficits in children with autism spectrum disorders

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Multisensory integration (MSI), the combination of various senses to form a single integrated experience of the world, is essential to everyday life. It is now widely claimed by clinicians and researchers alike that deficits in MSI are part of the phenotype of autism, although rigorous empirical evidence for this is sparse. The current study examined MSI in children (10-13 yrs.) with autism spectrum disorders (ASD) and typically developing (TD) children through analysis of dense-channel array event related potentials (ERPs) elicited in response to visual (V), auditory (A), and somatosensory (S) stimuli delivered alone or in simultaneous combination. The task was the detection of all stimulus events in a simple reaction time (RT) paradigm. Differences between multisensory (MS) and the summed responses of unisensory stimuli (US) were used as a measure of MSI. We have developed a unique trisensory "stimulation desktop" which delivers visual, auditory, and somatosensory stimuli in nearly the same location. Results demonstrate a lack of RT facilitation in excess of probability summation for multisensory stimuli for the ASD group. Unisensory ERPs are generally similar between the TD and ASD groups, however the pattern for the multisensory comparisons differed between groups, particularly for auditory/tactile conditions such that there was less difference between summed US and MS responses in the ASD group. The TD pattern typically showed decreased early (50-80 ms) activations in MS conditions compared with summed US data. These results are consistent with the suggestion (Rubenstein and Merzenich, 2003) that an altered excitation / inhibition ratio in cortical processing may underlie some aspects of the ASD phenotype. Further, "sensory defensiveness" and other idiosyncratic behaviors in ASD may occur if an obligatory experience of perceptual sensory unity eludes an individual due to over-excitation from common sensory experience.

Effects of Age on Multisensory Integration and Social Interaction

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Background: Efficient navigation of our social world depends on proper generation, interpretation and combination of social signals within different sensory systems. However, the influence of healthy adult ageing on multisensory integration of emotional and social stimuli remains poorly explored.

Method: The current study investigated the performance of 25 healthy older adults aged 60-80 years on unisensory (auditory and visual) and cross-modal tasks (audio-visual) related to emotion recognition. Performance was compared with 25 younger adults aged 19 - 40 years.

Results: Resulting data suggest that older adults display difficulty in recognizing negative emotions within auditory and visual domains when compared with young adults. In contrast, older adults performed as good as younger adults on positive and negative emotional recognition tasks where both congruent auditory and visual emotional information is presented at the same time.

Discussion: The findings suggest that older adults benefit from congruent multisensory information in social situations where sensory information from multiple modalities is integrated into part of multisensory neural network.

Audiomotor interactions during listening to improvised piano melodies

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Purpose of the study: The current study investigates the auditory perception of improvised and imitated piano melodies. Improvisation in music is a creative process during which musicians can choose relatively freely the specific notes they play and when to play them. Such an action can be described to be intention-based. On the other hand, imitating a phrase of music can be characterized as stimulus-based action – the notes of someone else's playing guide the action during imitative music playing. Recent brain imaging studies have shown differences in neural activity during the action of improvising and imitating melodies. We test whether there are differences in brain activations when jazz musicians listen to improvised and imitated piano melodies, i.e., the perception of the end products of different action modes. Such differences may be expected based on claims that action and perception recruit overlapping neural networks.
Methods: Recorded piano melodies that had been played over novel backing tracks of three contrasting jazz styles (swing, bossa nova, blues ballad) were used as stimuli. These melodies were either spontaneous improvisations or practiced imitations of the improvisations. Using event-related fMRI and a sparse sampling technique (interleaved silent steady state imaging, where longitudinal magnetization is maintained during silent periods), 10-second excerpts from these melodies were presented with backing during the silent periods. Following each stimulus presentation, 7 functional whole brain scans were recorded and participants (22 jazz musicians, who had on average 12.8 years of piano playing experience) indicated by key press whether the heard melody was improvised or imitated. Data were analyzed with SPM5 according to a 2 x 2 factorial design that took into account the objective classification of stimuli (real improvisations/real imitations) and subjective classifications based on participants' responses (judged improvised/judged imitated). After scanning, each participant's musical and jazz experience was assessed by a questionnaire. *Results:* Behavioral data show that participants could distinguish between improvised and imitated melodies with a correct response rate

(55%; range 44-65%) and a d-prime (.25; range -.30 to .83) that were significantly better than chance ($p<.001$). These performance rates were correlated with various measures of musical and jazz experience (e.g., number of hours, participants spent playing jazz together with other musicians). Listening to piano melodies revealed activation of a widespread network comprising auditory cortex, premotor area, supplementary motor area (SMA), and cerebellum (conjunction analysis of all listening conditions). Listening to real improvisations compared with listening to real imitations (objective classification) showed stronger activation in the amygdala region for improvisations. This result is in accord with the suggested role of amygdala in detection of stimuli that are behaviorally relevant. For the contrast based on the subjective classification, listening to melodies that were judged to be improvised compared with those that were judged to be imitated revealed stronger activations in a network including pre-SMA, frontal operculum and insula. This activation pattern could reflect a stronger motor simulation process during listening to melodies that are were judged to be improvised, which would be also consistent with studies showing stronger activation in pre-SMA during the act of improvising music.

Conclusions: Taken together, these findings suggest that differences in brain activation arise at two levels when listening to improvisations and imitations: one largely independent of listeners' judgments and the other more strongly linked with listeners' judgments.

The acquisition of Human EEG Data during Self-Motion on a Stewart Platform

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Purpose of the study: The human sense of movement and balance integrates vestibular information with visual and somatosensory information. Research into the neural correlates of vestibular processing has been hampered because the subject must remain in a fixed position, and consequently neither magnetic resonance imaging nor positron emitted tomography are suitable methods. Therefore, research on the neural correlates of linear self-motion in humans has typically used visual vection, which is self-motion induced by large-field visual motion stimulation during which the stationary subject perceives the moving visual surroundings as being stable and themselves as moving. This study investigated the feasibility of acquiring electroencephalography (EEG) data during self-motion in human subjects. Electroencephalography would appear to be a suitable candidate for recording neural activity during motion because modern EEG acquisition equipment is lightweight and portable. Furthermore, a Stewart motion platform provides an appropriate method of producing linear self-motion in a laboratory environment. There are, however, a number of potential drawbacks to using a Stewart motion platform in conjunction with EEG recording equipment. For example, noise could be introduced into the EEG signal from the motion of the actuators, the electrical noise of the platform power source, or from muscular activity of the subject as they compensate for the acceleration at the start and finish of the motion. If achievable, this would allow a new method for investigation of vestibular processing and multisensory interaction. Understanding the contribution of different sensory modalities to the human senses of balance and movement is a key task for aiding the elderly, as the processing of vestibular signals deteriorates over time, which can lead to postural instability and falls.

Method: Six subjects performed a visual oddball task – designed to evoke a P3 event-related potential (ERP) – under four different motion conditions on a Stewart platform. The motion conditions – stationary,

idle, slow and fast – were designed to ascertain if the Stewart platform produced electromagnetic noise which would mask EEG data. The P3 task was chosen as it is relatively simple to evoke and can be tested using various experimental paradigms and sensory modalities, making it a robust measure. The P3 task required the subject to respond when observing an infrequent visual stimulus. The visual stimuli were projected onto a large screen in the Stewart platform. EEG data were recorded using both a shielded system, the BrainAmp MRPlus, and separately using an unshielded Biosemi ActiveTwo system.

Results: Reliable P3 ERPs were found to be present under all motion conditions. The correlation among conditions during the interval -100ms to 600ms of the ERPs was at least 0.93. There were no artifacts caused by interference from the Stewart platform from both the shielded and unshielded systems. The number of rejected epochs was similar across all conditions.

Conclusion: The results of this study indicate that reliable EEG data can be obtained during self-motion on a Stewart platform, and that the task-independent vestibular input did not interfere with the visually-evoked P3 ERP. The Stewart platform did not introduce noise to the data. This finding is noteworthy for the ecological validity of further research into human motion.

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When hearing the bark helps to identify the dog: Semantically-congruent sounds modulate the identification of masked pictures

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We report a series of five experiments designed to assess the effect of audiovisual semantic congruency on the identification of visually-presented pictures. Participants made unspeeded identification responses concerning a series of briefly-presented, and then rapidly-masked, pictures. A naturalistic sound was sometimes presented together with the picture at a stimulus onset asynchrony (SOA) that varied between 0 and 533 ms (auditory lagging). The sound could be semantically congruent, semantically incongruent, or else neutral (white noise) with respect to the target picture. The results showed that when the onset of the picture and sound occurred simultaneously, a semantically congruent sound improved, whereas a semantically incongruent sound impaired, participants' picture identification performance, as compared to the white-noise control condition. A significant facilitatory effect was also observed at SOAs around 300 ms, whereas no such semantic congruency effects were observed at the longest interval (533 ms). These results therefore suggest that the representations of visual and auditory stimuli can interact in a shared semantic system when they refer to a common object or event. Furthermore, this crossmodal semantic interaction is not constrained by the need for the strict temporal coincidence of the constituent auditory and visual stimuli. We therefore suggest the audiovisual semantic interactions likely occur in a short-term buffer which temporarily retains the semantic representations of multisensory stimuli in order to form a coherent multisensory representation. These results are explained in terms of Potter's (1993) notion of conceptual short-term memory.

DAY 4 - THURSDAY

Capturing driver attention by activating the brain's defensive system

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We report a series of three experiments designed to assess the relative speed with which people initiated speeded head orienting responses following the presentation of spatial warning signals. Recent cognitive neuroscience findings have shown that our brain tends to treat stimuli occurring in peripersonal space as being somehow more behaviourally relevant and attention-demanding than stimuli occurring in extrapersonal space. These brain mechanisms may be exploited in the design of warning signals. Experiment 1 assessed the effectiveness of various different unisensory warning signals in eliciting a head-turning response to look at the potential source of danger requiring participants' immediate attention; Experiment 2 assessed the latency of a driver's responses to events occurring in the cued direction; Experiment 3 assessed the relative effectiveness of various warning signals in reorienting a person's gaze back to a central driving task while they were distracted by a secondary task. The results showed that participants initiated head turning movements and made speeded discrimination/braking responses significantly more rapidly following the presentation of a close rear auditory warning signal, than following either the presentation of a far frontal auditory warning signal, a vibrotactile warning signal presented to their waist, or a peripheral visual warning signal. These results support the claim that the introduction of peripersonal warning signals result in a significant performance advantage relative to traditionally-designed warnings. Warning systems that have been designed on constraints of the human brain offer great potential in the future design of interfaces.

Eye gaze and head orientation as spatial cues to visual and auditory targets: The head's wired for sound

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Research has indicated that spatial attention in humans is directed by other people's eye gaze (e.g., Driver et al., 1999). It is, however, currently unclear whether the orientation of another person's head also results in the spatial orienting of attention (George et al., 2001; Langton et al., 2000). We examined the effectiveness of eye gaze and head orientation in eliciting shifts of visual and auditory spatial attention. Participants had to identify visually- (Exp. 1) or auditorily-presented (Exp. 2) letters as rapidly as possible following the presentation of eye-gaze and head orientation cues (independently and in combination). Head direction cues influenced the speed of auditory target discrimination performance but no such effects were observed on visual target discrimination performance (see Fig. 1). These findings suggest that different types of social cue have different effects on the distribution of visual and auditory spatial attention. Our results also urge caution with regard to the interpretation of previous claims regarding the primacy of eye gaze cues in a hierarchical social attentional network.

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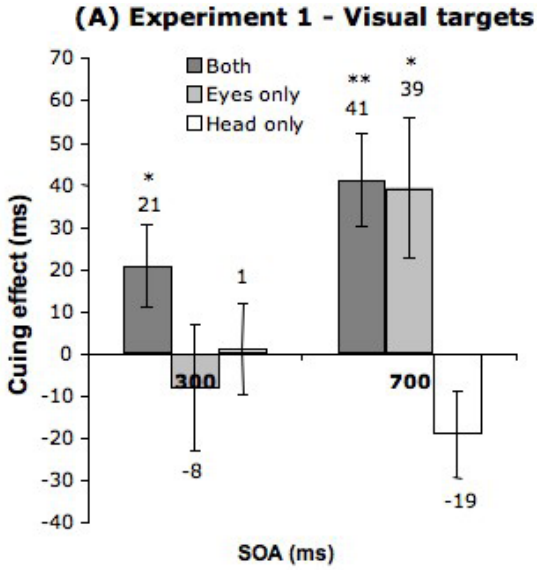
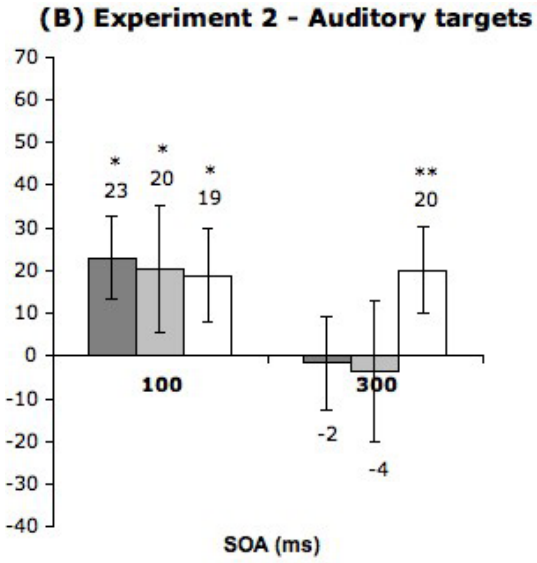
Fig. 1: Mean cuing effects for each cue type at each Stimulus Onset Asynchrony (SOA) used in each experiment (Exp. 1 (Panel A): 300 ms and 700 ms; Exp. 2 (Panel B): 100 ms and 300 ms). The numbers above the bars represent the mean cuing effect, the error bars represent the standard error of the mean, and the asterisks indicate cuing conditions in which the cuing effect was significantly different from 0 ms as indicated by apriori t-tests (* = $p<.05$, ** = $p<.01$, *** = $p<.001$, all one-tailed).





Contribution of visual and vestibular signals in extrastriate visual cortex to heading perception

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Heading perception is a multi-sensory process that involves both visual (e.g. optic flow) and vestibular (e.g. inertial motion) signals. We previously reported that activity in extrastriate visual cortex (area MSTd) is correlated with monkeys' perceptual judgments during performance of a heading discrimination task based on visual or vestibular cues. To test for a causal link between MSTd activity and heading discrimination, we used microstimulation and reversible inactivation techniques to artificially manipulate MSTd activity and observe the subsequent changes in the monkey's behavioral performance.

Methods: Heading stimuli were defined by optic flow, inertia motion or congruent combination of the two cues. Heading direction was varied in fine steps around straight forward in the horizontal plane. Monkeys were required to report whether their perceived heading was to the left or right of straight ahead. For microstimulation, during one-half of the trials, a mild electrical current (peak amplitude: 20 uA) was applied through a microelectrode placed in area MSTd. For inactivation, a small amount of muscimol (10mg/ml, 1~2ul) was injected through a canula placed in area MSTd. Chemical injections were applied bilaterally.

Results: 1, Microstimulation: In the visual condition, microstimulation of MSTd produced a statistically significant behavioral bias at 81/150 (54%) stimulation sites. Among the significant effects, the majority (86%) were in the direction predicted from the heading tuning of multi-unit activity at the stimulation site. At the population level, both monkeys showed a highly significant effect ($p<<0.001$). In the vestibular condition, microstimulation elicited a significant behavioral bias for only 16/150 (10.7%) sites. Among the significant effects, about half were consistent with the heading preference of multiunit activity. At the population level, neither monkey showed a significant stimulation effect ($p>0.1$). An examination of heading tuning for multiunit activity revealed substantially weaker vestibular selectivity than visual selectivity, suggesting that weak clustering of inertial motion signals in area MSTd limits the efficacy of microstimulation in the vestibular condition. In the combined condition, the effect was intermediate between the two single cue conditions. 2, Inactivation:

In the visual condition, inactivating MSTd significantly deteriorated the monkeys' heading discrimination performance ($p<<0.001$, $n=13$). The average psychophysical threshold increased about 3-fold compared to that in the control and recovery sessions. In the vestibular condition, the monkeys' performance was also significantly affected ($p<0.001$, $n=13$) after inactivation. However, the average threshold increased by only 30%, a much weaker effect than in the visual condition. In the combined condition, the inactivation effect was significant ($p<0.001$, $n=13$) and the average threshold increased by about 30%.
Conclusion: These results establish a causal link between MSTd activity and monkeys' heading perception based on visual and vestibular signals. However, based on the behavioral effects of microstimulation and inactivation, MSTd appears to play a more dominant role in heading judgments from visual signals alone than vestibular signals alone. The weak vestibular effects suggest that other areas may play significant roles in judging self-motion from vestibular cues.

Entrainment of Neuronal oscillations as a mechanism of attentional selection: human intracranial recordings

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A key functional property of slow oscillations is the rhythmic shifting of excitability in local neuronal ensembles (Lakatos et al., 2005). It has been shown in the monkey visual cortex that delta oscillations can entrain differentially to 2 interleaved streams of auditory and visual stimuli depending on the modality to which attention is paid, resulting in increased response to visually-attended stimuli (Lakatos et al., 2008). The goal of the present study was to extend these results to other parts of the cortex and to the human.

The experiment was run on 7 epileptic patients undergoing surgical evaluation and implanted with subdural electrodes over various parts of the cortex. The task before the patients was to detect either auditory or visual targets in a stream of alternating auditory and visual standard stimuli presented just above threshold. The stimulation rate in a given modality was1.54 Hz (delta rhythm), with a normally distributed random jitter.

Out of a total of 584 electrodes showing no or little pathological activity, we first selected 197 electrodes showing some entrainment to at least one of the stimulus streams (i.e. significantly non-uniform delta phase at the time of stimulation across trials, rayleigh test, $p<.05$ non-corrected). We then compared the phase of delta oscillations between auditory-attended and visual-attended trials. Out of 197 electrodes, 72 showed a significant phase difference (permutation test $p<.05$, corrected for multiple tests per patient), showing that attention can modulate the way delta rhythm is entrained to the stimulus stream in various parts of the brain.

Significant attentional phase shifts ranged from very small values (less than 15º) to complete phase reversals as observed in monkey V1.

The value of the phase shift was significantly correlated and inversely proportional to the amplitude of post-stimulus evoked activity, as indexed by a post-stimulus increase in phase-locking values (PLV) between 3 and 30 Hz in a 50-350ms post-stimulus time-window. In electrodes over the parietal and frontal cortex, the attentional phase shift was generally larger and not associated to an increase in PLVs, suggesting that, at least in these areas, entrainment could not be explained by evoked activity at the rate of stimulation.

In contrast, electrodes over the superior temporal (auditory) cortex, the occipital and subtemporal (visual) cortex and the primary motor/somatosentory areas showed higher PLVs, corresponding to evoked activity that might have hidden effects on ongoing delta oscillations. Interestingly. auditory and visual sensory areas showed classical attention effects, the PLVs increasing over the sensory cortex of a given modality when patients paid attention to this modality. Importantly, electrodes showing significant effects barely overlapped with those showing frequent or occasional interictal activity as identified by epileptologists. These results demonstrate that in the human brain, ongoing delta oscillations, reflecting variations in membrane excitability, can entrain to sensory streams in extended regions of the cortex and that this entrainment can be modulated to serve intermodal attentional selection, possibly leading to the classically observed increase in sensory responses to the stimuli.

Ventriloquist aftereffect reflects a shift in auditory likelihood functions

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Background: Several studies have demonstrated that perceptual decision making can be remarkably consistent with statistically optimal models. For example, human auditory and visual localization judgments closely resemble that of a Bayesian causal inference model (Körding et al., 2007), where the observer infers the underlying causal structure of the environment based on the available evidence and prior knowledge. While most of these studies characterize perceptual inference within a static environment, there is little known as to how this inference process changes when exposed to a dynamic environment. One of the mechanisms of the nervous system for coping with exogenous or endogenous changes is the continued maintenance of sensory processing through crossmodal recalibration. A common example is the Ventriloquist Aftereffect: the shift in perceived location of sounds (in isolation) that occurs after repeated exposure to consistent spatial discrepancy between auditory and visual stimuli. From a computational point of view, this change could reflect a shift in the auditory sensory representations (i.e., shift in auditory likelihood distribution), a decrease in the precision of the auditory estimates (i.e., increase in spread of likelihood distribution), a shift in the auditory bias (i.e., shift in prior distribution), or an increase/decrease in certainty of the auditory bias (i.e., the spread of prior distribution), or a combination of these. Purpose: We aimed to computationally characterize this perceptual recalibration effect. Because the aforementioned causal inference model allows estimation of likelihoods and priors, we can empirically test which one(s) of these quantities undergoes change after recalibration. Methods: During an exposure phase, observers performed a visual contrast change detection task, while passively exposed to flashes and noise bursts at varying locations along azimuth but with a consistent spatial discrepancy. In pre- and post-exposure sessions, observers were presented with auditory and/or visual stimuli and asked to localize each of the stimuli. Using the Bayesian causal inference model, for each observer, we empirically and quantitatively tested for any parametric changes in prior or likelihood distributions after exposure. We used normal distributions to represent the

likelihoods and priors over space, which resulted in 7 free parameters: the standard deviation of the auditory and visual likelihoods (2) and spatial prior (1), the mean of the spatial prior (1), the prior probability of a common cause (1), and the shift in the mean of visual and auditory likelihood functions (2). These parameters were fitted using 900 data points obtained from each subject in each of the pre-test and post-test sessions separately. Results: We found that after exposure, the auditory likelihood functions were shifted to the right (paired ttest, $p<0.001$) when the visual stimulus was presented to the right of the auditory stimulus during exposure, and vice versa ($p<0.001$) when the visual stimulus was presented to the left during exposure. No statistically significant shift was found in the mean of the prior over space, in the prior probability of a common cause, in the mean of the visual likelihood, or in the visual and auditory noise. All tests were corrected for multiple comparisons. Conclusion: This suggests that sensory recalibration observed in the ventriloquist aftereffect is achieved by updating the mean of the auditory likelihood using recent perceptual estimates. Recent studies have provided evidence that human responses follow the posterior distribution of combined cues; our results suggest that this internal estimator can also drive the recalibration process.

Top-down influences on the detection and discrimination of spatially-distributed auditory-somatosensory events

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Simple reaction times (RTs) to auditory-somatosensory multisensory stimuli are facilitated beyond predictions of probability summation not only when stimuli are delivered to the same location, but also when they are widely separated either between left and right hemispaces (Murray et al., 2005 Cerebral Cortex) or between front and rear spaces (Zampini et al., 2007 Neuropsychologia). While this pattern of effects might on the one hand depend (at least partially) on the particular body surface stimulated, results at this point indicate that the absolute spatial position is not the determining factor in whether or not facilitative effects vary between spatially aligned and misaligned multisensory conditions (Tajadura-Jimenez et al., 2009 Neuropsychologia). One interpretation of these findings is that they provide insights regarding the likely spatial representations within the brain region(s) mediating the effects. Here we addressed the possibility that top-down and/or task-related influences can dynamically impact such spatial representations and by extension the extent to which facilitative multisensory effects will be observed. Participants performed a simple detection task in response to auditory, somatosensory (vibrotactile stimulation of the left or right index finger and thumb), or simultaneous auditory-somatosensory stimuli that in turn were either spatially aligned or misaligned (e.g. auditory stimulation to the left and somatosensory stimulation to the right). In addition to the simple detection task, we also informed the participants that they would be queried from time to time (25% of trials) as to whether or not a given stimulus in a given sensory modality had been presented to the left or right on the preceding trial. Four possible probes were computed (2X2; sound or vibration with left or right) used for the eight conditions (four unisensory and four multisensory). Probes could be spatially congruent or not, thus yielding 16 different conditions in total. In this way, we sought to have participants selectively

attending to each spatial location, while nonetheless having them perform a simple detection task irrespective of spatial information. After a first set of analyses that failed to reveal a main effect of side of stimulation, data were collapsed across left-sided and right-sided presentations. Detection rates and RT were then analyzed with a repeated measures ANOVA using condition as the within subject factor (auditory, somatosensory, aligned, and misaligned). Subjects could reliably detect the stimuli >95% of the time with no reliable differences in detection rates across stimulus conditions ($F(3,6)=1.42$; $p=0.33$). By contrast, RTs significantly varied across conditions ($F(3,6)=31.45$; $p<0.0005$) and were faster to multisensory aligned and to multisensory misaligned conditions than either unisensory condition ($p<0.003$ in all cases). There was no evidence for a reliable difference between RTs to aligned and misaligned multisensory conditions ($p>0.48$). Preliminary analyses of the responses to probes inquiring about the spatial location of somatosensory stimuli suggest that performance sensitivity (d') is impaired for multisensory trials when the stimuli were spatially misaligned relative to unisensory trials ($t(8)=5.59$; $p<0.0006$). Taken together our results would suggest that while task demands do not affect the detection of the stimuli (when either spatially aligned or misaligned), the indication of the spatial position of a stimulus did vary with such. These results suggest there to be multiple stages of auditory-somatosensory interactions that are differentially susceptible to influences of task demands on spatial processing.

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Multisensory influences in auditory and superior temporal cortex

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Recent results from human imaging and electrophysiology demonstrate that the processing of acoustic information can be influenced by stimulation of other sensory modalities already at early stages in auditory cortex. Here we scrutinize the neuronal basis of these multisensory influences at different stages along the auditory processing streams. To this end we record neuronal responses in different regions of auditory cortex and in the upper bank of the superior temporal sulcus (STS) during stimulation with naturalistic audio-visual stimuli.

In caudal primary or secondary auditory fields only few neurons revealed significant visual influences. However in regions beyond the classical auditory cortex, their fraction increased considerably, and in association regions such as the upper bank STS both bimodal neurons and neurons with significant multisensory interactions were common. In fact, our results demonstrate a spatial topographical layout of modality preferences in the STS, which might provide a neural basis of sensory integration in this region. To characterize the effect of multisensory inputs at each of these processing stages we investigate the importance of stimulus congruency on multisensory interactions. In addition, to distinguish basic response modulation from sensory integration we use methods of information theory to determine whether visual input actually enhances the information encoded by neuronal responses about the stimulus. Altogether, our results provide first insights into how the impact of multisensory influences increases along a sensory processing pathway and start to shed light on where and how the neural representation of the sensory environment benefits from multisensory inputs.

DAY 4 - THURSDAY

Polymorphism of the mu-opioid receptor gene (OPRM1) and visuotactile congruency effect

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Polymorphism of the mu-opioid receptor gene (OPRM1) has been shown to reduce both the sensory and affective dimensions of pain by binding at opioid receptors. The activation of brain regions associated with the processing sensory intensity decreased linearly in relation to opioid analgesic drug concentrations, which was significantly less pronounced in OPRM1 118G carriers. It suggests that the OPRM1 might be associated to the somatosensory intensity also in the multisensory processing. By this perspective, we investigated the role of OPRM1 118A>G for multisensory processing using the paradigm of the visuotactile congruency effect. The participants grasped an expanded polystyrene cube with two vibration motors and 2 LEDs by the thumb and forefinger of their left hand. The task was to judge the location of the tactile stimuli. The visuotactile congruency effect was the RT difference between the congruent (e.g. both visual and tactile stimuli were presented at the forefinger) and incongruent condition. In the results, the 118A carriers showed the greater congruency effect than the 118A non carrier, which indicated the group difference by polymorphism of OPRM1 on visuotactile congruency effect. This suggests that there is the inherited difference on the visuotactile integration processing.

Multisensory disambiguation of a temporal pattern

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A compelling corpus of studies have shown that the integration of two weakly effective visual and auditory stimuli can have profound behavioural effects, both in enhancing perceptual sensitivity and improving orientation and localization performance. However, whether multisensory integration can also aid in disambiguating temporal patterns amidst the presence of noise is poorly understood. To examine the possible impact of this process on such performance, human subjects were asked to judge the presence or absence of a periodic sequence (target) of visual (Experiment A) or auditory (Experiment B) stimuli that were embedded in a complex background (i.e., noise). The background consisted of randomized sequences of visual and auditory stimuli ("distracters"). The target was a 1 Hz sequence of unisensory stimuli (Visual or Auditory) or bisensory (AV) synchronous stimuli presented in spatial coincidence, as if derived from a common event; or in spatial disparity as if derived from different events. When the AV stimuli were presented in spatial coincidence there was a significant increase in performance. The accuracy of target recognition improved significantly (in experiments A and B), and there was a significant increase in reaction speed (in experiment A) compared to that under each unisensory condition. In contrast, no significant effects were observed when the AV stimuli were spatially disparate. These results show that multisensory integration can aid in the disambiguation of periodic and therefore salient temporal patterns in a complex background, and suggest that it may be of substantial utility in detecting and identifying the sources of biologically relevant audio-visual events.

The ability of haptics to modulate the Ebbinghaus illusion

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Purpose: We investigated how the Ebbinghaus illusion (the phenomenon wherein the central circle looks larger if the circles around it are smaller in size and vice versa) could be modulated by haptics. Method: Ten university students (aged 21–22) observed the illusory figure under visual and bimodal conditions. Illusory figures composed of a central circle (5 cm in diameter) and five surrounding circles (3, 4, 5, 6, or 7 cm in diameter, size D) were presented one by one on a PC display. In the bimodal condition, the observers had to integrate the sizes of the visual and haptic central circles, which were congruent or incongruent in size. They simultaneously explored the haptic circle presented on the other side of the visual image by hand. Then, they decided the apparent size of the central circle among the comparison stimuli (4, 4.5, 5, 5.5, and 6 cm in diameter). Results: (1) In the visual condition, the Ebbinghaus illusion could be clearly found. The PSE (subjective equal size of the central circle) was larger than 5 cm when D = 3 cm, while it was smaller than 5 cm when D ≥ 4 cm. (2) In the bimodal condition, haptics modulate the amount of size illusion. Mean error score (The PSE −5 cm) of each central circle was significantly decreased by the haptic capture.

Multisensory interactions facilitate categorical discrimination of objects

Celine Cappe [1], Micah M. Murray [2]

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The present study investigated the extent to which the discrimination of everyday objects is affected under multisensory conditions. Recent evidence would suggest that visual articulator information can speed up auditory speech processing (van Wassenhove et al., 2005 PNAS), though it should be noted that in this study and more generally in the case of speech the visual component often precedes its auditory counterpart. Research investigating integration of synchronously presented auditory-visual object stimuli has focused instead on effects of attention and/or has limited the stimulus set to animals (Molholm et al., 2004 Cereb Cortex; Yuval-Greenberg and Deouell, 2007 J Neurosci). It thus remains unknown whether categorical discrimination of environmental objects, and by extension object recognition, benefits from multisensory stimulation either at a behavioral or neurophysiologic level. We focused here on the categories of living and man-made objects given previous research demonstrating these to engage (partially) dissociable brain networks (e.g. Murray et al., 2006 J Neurosci for the case of sounds; Gerlach, 2007 J Cogn Neurosci for the case of images). Participants were presented with auditory, visual, or simultaneous auditory-visual (AV) stimuli during a living vs. man-made discrimination task. The auditory stimuli were those used in our prior works and were controlled both spectro-temporally and psychophysically. The visual stimuli were derived from controlled image sets (Snodgrass and van der Waart, 1980 J Exp Psych). Reaction times (RTs) were submitted to a 2 x 3 repeated measures ANOVA using within subject factors of category (living vs man-made) and sensory modality (A, V, AV). While RTs were generally slower for auditory than either visual or multisensory conditions, there was no evidence that RTs differed between visual and multisensory conditions. Likewise, there was no difference between RTs for each category. Thus, there was no support for multisensory facilitation of behavior. By contrast,

our ongoing electrical neuroimaging analyses revealed there to be facilitated discrimination of object categories when subjects were presented with multisensory versus either unisensory condition. Both auditory and visual conditions exhibited topographic differences between living and man-made object categories at ~140ms, indicative of configuration changes in the intracranial sources active in response to these object categories when presented visually or acoustically. However, following multisensory stimulation, this differential effect occurred ~20ms earlier. While not necessarily facilitating the earliest stages of categorical discrimination, these results nonetheless suggest that object recognition processes in vision and audition interact and can facilitate one another under multisensory conditions.

Effects of preparing a manual movement towards and away from the body on visual and tactile probe detection

José Van Velzen, Leola Thomas-Chirnside

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The experiment presented here investigated the links between action and attentional enhancement of sensory processing for manual movements in depth in peripersonal space. To this end, detection of visual and tactile probe stimuli presented during response preparation was compared for movement towards and away from the body in a Go/Nogo paradigm. Further, to assess the spatial distribution of movement-related effects on tactile and visual processing, probe were presented from locations within and outside the area of pragmatic space of the response hand.

An auditory cue instructed to prepare a movement towards or away from the body. Execution of the manual response had to be withheld until a 'go' signal was presented. In a proportion of trials, a tactile or a visual probe stimulus was presented during the interval between the cue and the 'go' signal.

Somatosensory probe stimuli were presented at one of three locations aligned in depth with the goal location of the movement towards the body in depth (sternum, left/right shoulder). Visual probe stimuli were presented aligned in depth with the goal location of the movement away from the body (midline, left/right visual field). Participants were instructed to vocally respond to visual and tactile probes and withhold their manual response until the Go signal was presented. After the 'go' signal the manual movement was executed with the right hand.

Manual reaction times were faster for movements towards than movements away from the body. Further, when a movement away from the body was being prepared, vocal reaction times were fastest for stimuli on the right and this was true for both visual and tactile probes. When a movement towards to the body was prepared, vocal reaction times were faster to probes presented on the left, for both tactile and visual probes.

These results suggest that the spatial distribution of the effects of movement preparation on visual and somatosensory processing in peripersonal space is shaped by the pragmatic space of the response hand, which in the present experiment was right-lateralised for external space, but left-lateralised for the probed area of body space.

Multimodal integration in perceiving direction of self-motion from visual and vestibular stimulation

Toshio Kubodera [1], Philip M. Grove [2], Shuichi Sakamoto [3], Yo-iti Suzuki [3], Kenzo Sakurai [1]

[1]Tohoku Gakuin University, [2]The University of Queensland, [3]Tohoku University

We measured observers' perceived direction of self-motion resulting from the simultaneous presentation of visual and vestibular information, each simulating a different direction of motion. Sakurai et al. (2003) reported that when observers are presented vestibular stimulation consistent with rightward/leftward motion and visual stimulation consistent with forward/backward motion, they perceive themselves as moving in a direction intermediate to the directions specified by visual and vestibular information. Due to technical limitations, Sakurai et al. only employed one level of vestibular stimulation consistent with rightward/leftward motion, and the rate of expansion/contraction of the visual stimuli was not precisely controlled. To extend their study, we explored multiple levels of vestibular stimulation consistent with different motion trajectories, and systematically varied the rate of expansion/contraction of the visual stimuli using computer-graphics. In experiment 1, we measured the apparent direction of self-motion during oscillations on the swing while the observer was seated at various orientations relative to the objective trajectory of the swing motion and viewed expanding/contracting optic flow consistent with forward/backward self-motion via a head-mounted display. The frequency and maximum displacement (amplitude x 2) of the swing were constant at 0.33Hz and 60 cm respectively. Observers performed a rod-pointing task to report the perceived direction of self-motion. Only two of five observers perceived intermediate diagonal self-motion when the discrepancy between the direction of motion specified by optic flow and that specified by vestibular input was less than 90 degrees, meaning visual information affected the perceived direction of self-motion. Others, however, reported the veridical direction of their body motion ignoring the visual input. One possible reason for this failure to fully replicate Sakurai et al. is the magnitude of the vestibular signal was too large relative to the visual signal. Therefore, in experiment 2, we measured the apparent direction of self-motion again, reducing the displacement of the swing to 10 cm and the direction to only rightward/leftward, but systematically varying the

visual information. Optic flow consisted of concentric sine wave rings (0.084 cpd) whose spatial phase oscillated between 0 (no motion), +/-270, and +/-540 degrees in order to generate different magnitudes of visual expansion/contraction independently of vestibular information. Most observers reported perceived directions intermediate to those specified by visual and vestibular information, that is, forwards and to the right (left) when the visual expansion was synchronized with the rightward (leftward) body motion. However, the perceived directions of self-motion did not clearly vary with the magnitude of optic flow. These results suggest that integration of visual and vestibular information is a weighted combination of both inputs when the discrepancy between them is small and their strengths are appropriately balanced.

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A Matter of Perspective: Exposure to third- as opposed to first-person perspective during walking enlargens peripersonal space

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[1]EPFL SV BMI LNCO, [2]EPFL VRLab

Technology has come a long way since Stratton (1889) who built a rudimentary yet innovative setup allowing him to watch his body from the viewpoint of an other person (third person perspective or 3PP) while he was walking. More recently, behavioral studies have shown that bodily processing can be manipulated using variations of a Strattonian 3PP setup, but in standing or sitting observers (Ehrsson, 2007; Lenggenhager et al., 2007, 2008). Here, we present a novel set-up (and experimental data) allowing the presentation of stimuli during locomotion (as well as afterwards) from a 3PP or the habitual-first person perspective (1PP) of the participant.

The present experiment modified a virtual reality (VR) set-up (Salamin et al., 2006) in order to investigate the range and malleability of peripersonal space following prolonged exposure to either 3PP or 1PP, while participants wore the experimental setup and walked freely for 15 minutes. The device consisted of a rigid backpack, a camera and a head mounted device (HMD) to which the video captured from the camera was relayed in real time. In order to estimate the range of peripersonal space (defined here as grasping space; i.e. Grüsser and Landis, 1991) we asked the participants immediately after 1PP or 3PP exposure to judge the interceptability of a ball projected on the HMD (ball catching task). On the HMD, a ball originated from a fixed point and travelled towards the participant at different trajectories (final horizontal distance from the participant was 20cm, 60cm, or 150cm). Participants were asked to respond if they could catch the ball or not through a serial response box. Trajectories and perspectival conditions were counterbalanced across participants.

Analysis of the mean number of "caught ball" responses of 11 participants across different conditions showed an expected main effect between different stimuli (20cm, 60cm, 150cm; $p<.001$) with decreasing number of catch responses for increasing final distances.

Yet, we also found a significant perspective x stimulus interaction ($p<.001$) based on 1PP-3PP differences only for the intermediate final distance of 60cm. These data reveal a functional extension of peripersonal grasping space based on perspectival cues during the free walking phase which was unrelated to the task. We discuss our data with respect to the more well know phenomenon of prism adaptation, multisensory and sensorimotor coding in peripersonal space, and observations in neurophysiology and neuropsychology.

Audiovisual integration of emotional signals from solo improvisation

Karin Petrini, Phil McAleer, Frank Pollick

Department of Psychology, University of Glasgow

Introduction
The multisensory nature of affect perception has scarcely been investigated, especially when it comes to music. In the present study we applied a paradigm often used in face-voice affect perception to music solo improvisation in order to examine how the emotional valence of sound and gesture are integrated when perceiving a 'unique' emotion.

Method
A set of short movies was obtained by asking two musicians (a drummer and a saxophonist) to improvise with their instrument and communicate happiness, sadness, anger, fear, disgust, surprise, and neutral (Figure 1a). Three emotions (anger, happiness and neutral) for the drummer and three (surprise, sadness and happiness) for the saxophonist were obtained by running a pilot experiment with 15 participants. These movies (i.e. congruent conditions) were manipulated to obtain audio only and video only versions, as well as a series of incongruent conditions. Forty-eight movies were shown to 20 musical novices, who judged the perceived emotion and rated the strength of each emotion.

Results
Participants perceived the intended emotion at a level above chance for all the 3 saxophone stimuli and for the drummer stimulus representing anger. Facilitation in perceiving the intended emotion was obtained for the congruent bimodal condition compared to the bimodal incongruent conditions (see Figure 1b for an example). Also a congruent bimodal facilitation was found when comparing this condition to audio only and video only, however the extent of this facilitation changed with instrument and emotion.

Conclusion
We integrate visual and auditory signals when perceiving emotion

from music improvisation. However, the auditory signal appears to be 'dominant' in the perception of affective expression, except when the emotional valence of the auditory information is ambiguous. Concluding, the results are in line with those of face-voice affect perception, suggesting that a similar process subtends both means of communication when perceiving affect from multisensory events.

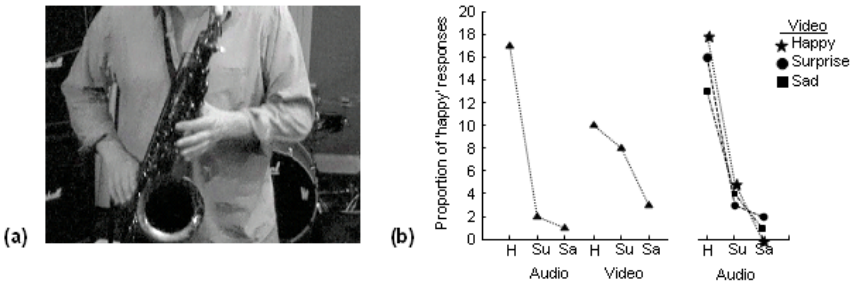

Figure1. (a) Frame sample from the 'surprise' clip. **(b)** Observed judgements of 'happiness' for H (happy), Su (surprise), and Sa (sadness) saxophone conditions. Audio only and video only results are shown on the left, while bimodal results on the right.

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Oral Session 4: Modelling and brain mapping

10:30 – 12:30

10:30 – 10:50

Phase coherence evolution in cortical networks: adaptation to audiovisual stimulation with fixed inter-modality asynchrony

Abdelhafid Zeghbib [1], Antje Fillbrandt [1], Frank W. Ohl [2, 1]

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[2]Institute of Biology, Magdeburg University, Germany

Continued stimulation with an auditory and visual stream of input, in which the inter-modal asynchrony is kept constant, is known to alter perceptual functions in humans, like the perceived temporal relationship between events in the two sensory modalities (e.g. Fujisaki et al, 2004, Nature Neuroscience; Vroomen et al, 2004, Cognitive Brain Research). In order to explore potential neuronal mechanisms that mediate such phenomena, we have subjected rodents (Mongolian gerbils, Meriones unguiculatus) to a similar protocol and have analyzed coherence between oscillatory components of local field potential (LFP) activity measured in auditory and visual cortex. Oscillatory coherence in brain dynamics can be an expression of its self-sustained behavior and is also considered to reflect integration of sensory input. For example, coherence is discussed as a substrate for binding near-synchronous, but distinct, sensory features into the perception of whole objects. On longer time scales, neither the perceptual role nor the neuronal mechanisms of integration are well understood.
Here, we study coherence, between auditory and visual local field potentials, before (only tone stimulus), during and after (only tone stimulus) exposure to streams of paired tone-flash stimuli (50 ms stimulus durations, fixed 200 ms stimulus onset asynchrony, randomized intervals between the audiovisual stimuli ranging from 1 to 2 s, stimulation for 10 daily sessions with approx. 750 repetitions). Figure 1 shows the three types (in-phase, anti-phase and stationary-shift phase) of coherence considered in this study. We analyzed interaction dynamics of auditory and visual cortical local field potentials in the broad band from 7 to 200 Hz. We introduced a Phase Coherence

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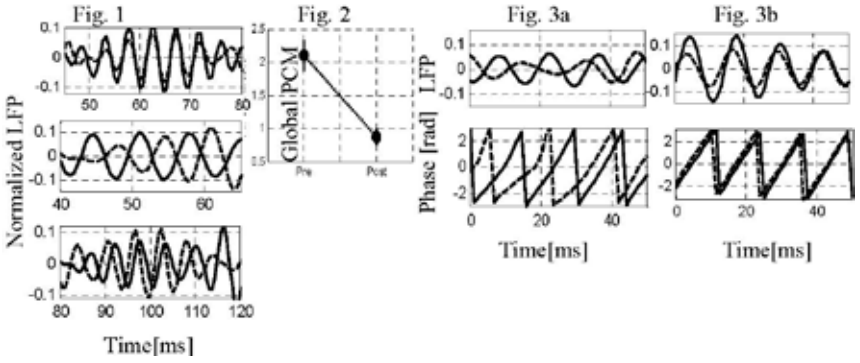
Metric (PCM) to calculate the phase coherence distance (derivative of phase difference) between auditory and visual cortex activities. Effective modulation of neuronal activities and evolution of phase-coherent states of LFP signals in both areas involving multiple band frequencies within 50 ms of the tone stimulus, have been observed in a continuous enhancement over multiple recording sessions.

Our data indicate, first, that continued presentation of sequentially paired audiovisual stimuli created a dynamical process of phase coherence as a potential physiological correlate of the altered cortical processing during adaptation. Secondly, we found that after the audiovisual adaptation sessions responses of visual cortex to auditory stimuli were increased relative to pre-adaptation sessions. We observed a significant enhancement of Global PCM averaged across all frequencies bands (Fig. 2, PCM+95% confidence intervals). Figure 3 shows a representative example (for the frequency band 82-93 Hz) of increased phase coherence between auditory (continuous) and visual (dashed) LFP after audiovisual adaptation (b) as compared to before adaptation (a). Top panels depict the LFPs in the respective filter band, bottom panels the corresponding phases.



Oral Session 4: Modelling and brain mapping

10:50 – 11:10

Tactile and Auditory Cues to Communicate Multiple Levels of Information

Ellen C Haas, Christopher Stachowiak, Timothy White, Krishna Pilalamarri, Theodric Feng
U.S. Army Research Laboratory

There has been a significant increase of empirical work on multisensory integration over the past years in applications such as navigation, guidance, and warnings. Many researchers (Sarter, 2006; Van Erp, 2002) explored the design of tactile cues to communicate one level of warning information (e.g., type or direction of event). However, little research has been conducted to explore the design of tactile cues to communicate multiple levels of information (type and direction of event), and how to integrate tactile cues with auditory signals in a multisensory display. This talk will describe two laboratory studies conducted to examine 1) the effectiveness of different tactor configurations and temporal signal parameters in communicating multiple dimensions of information (signal type and direction); and 2) the integration of tactile with auditory cues to provide redundant and non-redundant multisensory warning information. Response time and accuracy were measured. Data from the first experiment indicated that participants experienced confusion when those activations were in the same physical region due to different body/limb orientations. Implications of user body orientation while using tactile cues will be discussed. Results from the second experiment suggest that redundant presentation of auditory and tactile information is most efficient. The implications of this work for displays used in robotics, teleoperation and avionics applications will be described.

Sarter, N.B., (2006). Multimodal information presentation: Design guidance and research challenges (2006). A.M. Bisantz (Ed.) Cognitive Engineering Insights for Human Performance and Decision Making, International Journal of Industrial Ergonomics, 439-445.

Van Erp, J.B.F. (2002). Guidelines for the use of vibro-tactile displays in human computer interaction, Proceedings of Eurohaptics, Edinburgh, 18-22.

Oral Session 4: Modelling and brain mapping

11:10 – 11:30

Phonetic learning in audiovisual speech

Jean Vroomen

Tilburg University

In the ventriloquist illusion, the perceived location of a target sound is displaced toward a light flash delivered simultaneously at some distance, despite instructions to ignore that flash. Moreover, if subjects are exposed to displaced sound/light flashes for some time, aftereffects in sound localization can be observed, as unimodal target sounds are shifted in the direction of the flashes seen during the preceding exposure phase. Presumably, this shift reflects an adjustment in the sound localization system that minimizes the discrepancy between the auditory and visual signals (i.e., recalibration). The same kinds of adaptive aftereffects are by now also well documented for audiovisual speech. For example, if an ambiguous sound halfway between /b/ and /d/ is dubbed onto the video of a face saying /b/, there is not only an immediate bias by the lipread information (i.e., subjects report to 'hear' /b/), but also an aftereffect as the once ambiguous sound is now identified as /b/ right away. In this example, it is thus the lipread information that 'teaches' the auditory system how to interpret the initially ambiguous sound. In my talk, I will compare recalibration with another phenomenon - 'selective speech adaptation'- that may look similar, but is nevertheless very different. I will present data showing that recalibration, - but not selective speech adaptation -, only occurs if the sound and lipread signal are assigned to the same phonetic event. Moreover, I will present EEG and fMRI data related to brain processes underlying recalibration.

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Oral Session 4: Modelling and brain mapping

11:30 – 11:50

Inverse effectiveness in BOLD-response and its behavioural relevance in object categorization

Uta Noppeney, Sebastian Werner

Max Planck Institut for Biological Cybernetics

Inverse effectiveness has been invoked as a principle to describe synergistic effects of multisensory integration in neuronal and behavioural responses as a function of stimulus properties (e.g. intensity) or efficacy. We characterized 'inverse effectiveness' and its behavioural relevance at the macroscopic level, as provided by the fMRI BOLD-response, based on (1) stimulus-induced and (2) intrinsic response variability across voxels or subjects during object categorization. Subjects categorized audiovisual object stimuli with the relative informativeness (i.e. degradation) of the auditory and visual inputs being manipulated factorially. Controlling for low-level integration processes, higher-level audiovisual integration was observed selectively in the superior temporal sulci (STS) bilaterally. (1) Consistent with the law of inverse effectiveness, auditory and visual informativeness determined the operational modes of audiovisual integration in STS similarly to the influence of physical stimulus intensity in the superior colliculus: while multisensory interactions were primarily subadditive and even suppressive for intact stimuli, additive effects were observed for degraded, near threshold stimuli. (2) Exploiting intrinsic variability across voxels and/or subjects, we demonstrate that superadditivity for audiovisual stimuli increases with decreasing unimodal responses. This inverse relationship could be explained by inherent statistical dependencies between superadditive and unimodal responses. Nevertheless, the superadditive responses in STS (and only in this region) were related to subjects' audiovisual behavioral benefit: only subjects that benefited from multisensory integration exhibited superadditive interactions, while those that did not benefit showed suppressive interactions. In conclusion, the (super) additive and subadditive integration modes in STS are functionally relevant and related to behavioral indices of multisensory integration with superadditive interactions mediating successful audiovisual object categorization. We argue that inverse effectiveness trends in neuronal and behavioural responses may be intimately related and mutually predictive.

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Oral Session 4: Modelling and brain mapping

11:50 – 12:10

ERP Evidence for early cross-modal integration in visual selection

Jan Theeuwes, Erik van der Burg, Chris Olivers, Durk Talsma, Adelbert Bronkhorst

Cognitive Psychology, Vrije Universiteit

Recently we have demonstrated that synchronized auditory signals can greatly increase the saliency of visual target events in cluttered, continuously changing displays [Van der Burg, Olivers, Bronkhorst, and Theeuwes. (2008) Journal of Experimental Psychology: Human Perception and Performance. The sound makes the visual target pop out. This "pip and pop" effect occurs even though the sound carries no information on the location or identity of the target, as long as it is synchronized with the visual event. Here we report evidence from EEG data that the pip and pop effect results from audio-visual integration occurring at the early (preattentive) stages of processing. The audio-visual integration boosts the salience of visual signal such that it captures attention. Participants performed a visual search task with displays consisting of a multitude of oblique bars that continuously flipped between different orientations. The target was a bar that changed to horizontal or vertical, and the task was to indicate its orientation with an unspeeded response. Accuracy data showed the occurrence of the pip and pop effect: observers were better able to detect the target when it was accompanied by a sound, compared to when no sound was present, or when the sound was synchronized with a distractor instead. EEG analysis revealed an early modulation of the event-related potential (ERP) around 50 ms from target onset, when a tone was synchronized with the target, compared to the summed activity of those conditions in which only the auditory or only the visual signal was present. Around 250 ms, a lateralized ERP component (the N2pc) to the target was observed reflecting the capture of spatial attention to the location of the target. This component was followed by an increased P3 reflecting target identification. We conclude that audio-visual integration boosts the salience of the visual event causing it to gain priority over competing visual events.

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Oral Session 4: Modelling and brain mapping

12:10 – 12:30

Multisensory learning: from calibration, to associative learning to perceptual learning

Ladan Shams [1], Robert Jacobs [2], Aaron Seitz [3], Robyn Kim [4]

[1]UCLA, [2]University of Rochester, [3]UC Riverside Dept of Psychology, [4]UCLA Department of Psychology

Multisensory learning and adaptation can be classified into three categories: A) one modality calibrating another modality, B) the two modalities becoming associated together, and C) one modality facilitating learning in another modality. We will present a Bayesian network framework that unifies all three types of phenomena, and present experimental results exemplifying each of the three categories of learning. Although these three forms of learning appear very different from each other, we argue that they all fit within the same Bayesian network framework. For all three classes of phenomena, this computational viewpoint suggests that the crossmodal signal provides feedback and error information that can be used by each individual sensory system for learning. As an example of class A, we will discuss a study showing that haptic information can teach visual modality by adjusting the relative weights of the different visual depth cues (Atkins, Fiser, & Jacobs, 2001). As an example of class B, we will present data showing how associations between auditory and visual stimuli can occur automatically in the context of a statistical learning paradigm (Seitz, Kim, van Wassenhove, & Shams, 2007). Finally, as an example of class C, we will present results showing facilitation of visual perceptual learning by sound. We show this in the context of a motion detection task where subjects are presented with correlated auditory and visual motion directions. When auditory and visual motion directions are congruent (i.e., in the same direction) during training subjects show greater improvements in their ability to detect the visual motion direction (in the absence of sound) compared to when they are trained with only visual stimuli (Seitz, Kim, & Shams, 2006) or when trained with incongruent auditory and visual motion directions (Kim, Seitz, & Shams, 2008). Together these results show how our brain is able to associate stimuli between the senses and then use these associations as teaching signals to improve learning within each modality.

DAY 4 - THURSDAY

Symposium 6: Plasticity and Synergy in Multisensory Integration

2:00 – 4:00

Chair: Barry Edward Stein, Wake Forest University School of Medicine

Speakers:
Terrence R Stanford, *Wake Forest University School of Medicine*

Benjamin Rowland, *Wake Forest University School of Medicine*

John G McHaffie, *Wake Forest University School of Medicine*

Elisabetta Làdavas, *University of Bologna*

Overview:
Barry E. Stein will introduce the issues by briefly describing an early plasticity and compensatory mechanism that is restricted to the various sensory-specific components of the cortico-collicular pathway, a pathway that is critical for multisensory integration in the superior colliculus (SC), as well as for SC-mediated attentive, orientation and localization function.

Terrence R. Stanford will discuss the nature of the influence of this cortico-collicular pathway by detailing how its components operate, and by identifying a crucial synergy among them. This synergy must be expressed for the cortico-collicular projection to facilitate mulitsensory integration in its target SC neurons.

Benjamin Rowland will present data indicating that the functional plasticity in this system is not restricted to early life. Under the proper circumstance adult experience with cross-modal cues can compensate for early deprivation at the neuronal and behavioral levels. He will discuss how these findings in animal models might explain human subject performance on multisensory tasks after early sensory dysfunctions are corrected later in life (e.g., surgical removal of congenital cataracts, hearing aids or cochlear implants).

John G. McHaffie will also deal with adult plasticity in multisensory integration. He will show how cross-modal cues can be used in a behavioral training paradigm to ameliorate the visual hemineglect induced by unilateral removal of all contiguous visual cortices in adult animals, the physiological changes that occurs in the superior colliculus multisensory neurons as a consequence of this cross-modal training, and the dependence of these behaviorally-induced changes on multisensory regions of cortex.

Elisabetta Làdavas will show how this multisensory integration strategy has proved effective in the rehabilitation of patients with stroke-induced hemianopia, and its possible applicability to other patient populations.

Symposium 6: Plasticity and Synergy in Multisensory Integration

Developmental Plasticity in the Cortical Control of Multisensory Integration in the Superior Colliculus

Barry E. Stein

Wake Forest University School of Medicine

The ability of cat superior colliculus (SC) neurons to synthesize information from different senses depends on influences from two areas of the cortex: the anterior ectosylvian sulcus (AES) and the rostral lateral suprasylvian sulcus (rLS). Reversibly deactivating the inputs to the SC from either of these areas in normal adults severely compromises this ability in individual neurons and the SC-mediated behaviors that depend on it. In the current studies we found that removal of these areas in neonatal animals precluded the normal development of multisensory SC processes. At maturity there was a substantial decrease in the incidence of multisensory neurons, and those multisensory neurons that did develop were highly abnormal. Their cross-modal receptive field register was severely compromised, as was their ability to integrate cross-modal stimuli. Similarly, the SC-mediated behaviors dependent on this capacity were also eliminated. Apparently, despite the impressive plasticity of the neonatal brain, it cannot compensate for the early loss of these cortices. Surprisingly, however, neonatal removal of either AES or rLS had comparatively minor consequences on these properties at either the single neuron or behavioral levels. At maturity multisensory SC neurons were quite common: they developed the characteristic spatial register among their unisensory receptive fields and exhibited normal adult-like multisensory integration. Similarly, animals showed the characteristic benefit to multisensory integration in initiating and guiding orientation and approach behaviors. These observations suggest that during early ontogeny, when the multisensory properties of SC neurons are being crafted, AES and rLS may have the ability to compensate for the loss of one another's cortico-collicular influences so that normal multisensory processes can develop in the SC. Whether similar compensatory processes could be initiated in adult animals remains to be determined. Supported by NIH grants EY016716 and NS 36916.

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Symposium 6: Plasticity and Synergy in Multisensory Integration

Multisensory Integration in the Superior Colliculus Requires Synergy among Cortical Inputs from Modality-Specific Subregions of the Anterior Ectosylvian Sulcus

Terrence R. Stanford

Wake Forest University School of Medicine

Influences from the visual (AEV), auditory (FAES) and somatosensory (SIV) divisions of the cat anterior ectosylvian sulcus (AES) play a critical role in rendering superior colliculus (SC) neurons capable of multisensory integration. However, it is not known if this is accomplished via their independent sensory-specific actions or via some cross-modal cooperative action that emerges as a consequence of their convergence on SC neurons. Using visual-auditory SC neurons as a model, we examined how selective and combined deactivation of FAES and AEV affected SC multisensory (visual-auditory) and unisensory (visual-visual) integrative capabilities. Cryogenic deactivation of either FAES or AEV eliminated the multisensory response enhancement that is characteristic for SC neurons, an effect that was only marginally greater when both were deactivated simultaneously. These results indicate that SC multisensory integration depends on the cooperative action of distinct subsets of unisensory corticofugal afferents; afferents whose sensory combination matches the multisensory profile of their midbrain target neurons, and whose functional synergy is specific to rendering SC neurons capable of synthesizing information from those particular senses. Supported by NIH grants EY016716 and NS 36916.

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Symposium 6: Plasticity and Synergy in Multisensory Integration

Long-term Plasticity in SC Multisensory Integration: the Acquisition of Multisensory Integration Capabilities During Adulthood

Benjamin Rowland

Wake Forest University School of Medicine

It has been shown that the ability of neurons in the superior colliculus (SC) to integrate information across sensory modalities depends on inputs from unisensory neurons in specific regions of association cortex (i.e., the anterior ectosylvian sulcus and rostral lateral suprasylvian sulcus in the cat). Temporary deactivation of these regions unilaterally during a circumscribed developmental window (using slow-release Elvax-muscimol implants) precluded the normal development of multisensory integration in SC neurons and their associated behaviors (localization/orientation) in the affected hemifield when assessed at 1 year of age. These deficits were therefore long-lasting and appeared permanent. However, when animals were later examined at 5 years of age, multisensory enhancements were evident in behavior on both sides of space. Physiological examinations revealed that, in the same animals, SC neurons on both sides of space showed multisensory enhancement in their responses to coincident cross-modal stimuli: multisensory responses contained more impulses and had shorter latencies than the responses to the most effective of these modality-specific component stimuli. These data suggest that 1) specific regions of association cortex are the vehicle through which multisensory integration in the SC develops postnatally, 2) early interventions that deactivate these regions during circumscribed windows of time yield long-lasting and substantial deficits in multisensory integration in the SC, 3) However, plasticity in the development of SC multisensory integration is not limited to a circumscribed period of the first few months of postnatal life: the capacity to develop multisensory integration is also present in the adult, and although its time course appears far more protracted, its potency once developed is no less robust. Supported by NIH grants EY016716 and NS 36916.

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Symposium 6: Plasticity and Synergy in Multisensory Integration

Cross-modal Rehabilitative Training Ameliorates Visuomotor Deficits Produced by Visual Cortex Lesions

John G McHaffie

Wake Forest University School of Medicine

The superior colliculus (SC) requires influences from visual cortex to play its critical role in mediating contralateral visual orientation: unilateral visual cortex lesions eliminate this capacity and induce an enduring contralateral hemineglect. Given that auditory cues can have a profound influence on visual processing in certain behavioral circumstances, we posited that multisensory cortical regions might be recruited to compensate, in part, for the lost visual cortex. We tested this possibility with a rehabilitative strategy involving a cross-modal training paradigm. Cats with lesion-induced visual hemineglect were trained to orient to spatially and temporally coincident multisensory (auditory-visual) cues in the neglected hemifield. After one month of training, the cats had permanently regained the ability to orient to visual cues in the previously neglected hemifield whereas their untrained counterparts did not. Subsequent removal of ipsilesional anterior ectosylvian sulcus (AES) eliminated this reinstated visuomotor capacity, despite the fact that AES lesions normally have no effect on visual orientation behaviors. Presumably, repetitive orientation elicited by the auditory component of the cross-modal cue induced use-dependent alterations in the remaining neural architecture that ultimately re-established associations between visual cues and motor acts. Electrophysiological data suggested a neural correlate of this behavioral recovery: after cross-modal training, ipsilesional SC neurons regained robust visual responsiveness that had been lost following visual cortex lesions. Taken together, these data suggest that a functionally remodeled cortico-collicular circuit emerges as a consequence of cross-modal training that can compensate for the deleterious behavioral and physiological effects of visual cortex lesions. Supported by NIH grant NS35008.

DAY 4 - THURSDAY

Symposium 6: Plasticity and Synergy in Multisensory Integration

A Multisensory-based Approach to the Recovery of a Unisensory Deficit

Elisabetta Làdavas

University of Bologna

The human brain is provided with a flexible audio-visual system. This system interprets and guides responses to external events according to the spatial alignment, temporal synchronization and effectiveness of modality-specific signals. Here I will explore the possibility that such a system might represent the neural correlate of sensory compensation after damage to one sensory pathway. This hypothesis will be developed by considering results from behavioural studies in which spatial information from one sensory modality has been rendered weakly effective (healthy subjects) or damaged by a cerebral lesion (patients with visual field defect or visual neglect). In the first part, I will discuss evidence for the pivotal role of the superior colliculus-extrastriate pathway in responding to cross-modal stimulation when an overt orienting response is required. In the second part, I will examine the relevance of this pathway for the short and long-term effects of audio-visual stimulation on the visual and spatial impairments following damage to the geniculo-striate pathway.

Oral Session 5: Other

4:30 – 6:00

4:30 – 4:50

Sensitivity to audiovisual correspondence depends on temporal structure

Rachel Denison, Jon Driver, Christian Ruff

UCL Institute of Cognitive Neuroscience, University College London, Wellcome Trust Centre for Neuroimaging at UCL, Institute of Neurology, University College London

Studies investigating the perception of audiovisual simultaneity often start from the idea that the brain must compensate for the different arrival times and processing delays of auditory and visual events in order to determine whether two events were physically synchronous. We explored a very different notion. Given that our audiovisual experiences are extended in time, we asked whether the brain might use a strategy of temporal pattern matching to integrate audiovisual events. Visual and auditory event streams with the same pattern over time (like the lip movements and speech sounds of a person talking) are unlikely to match by chance, and therefore are likely to have a common cause. Such temporal pattern matching could be a reliable cue for multisensory integration that does not rely on precise sensory timing or stimulus-dependent compensation processes. In this study, we asked participants to match irregular streams of simple auditory and visual stimuli in a 2-alternative forced choice task. We showed that people could use common temporal pattern as an audiovisual correspondence cue over a wide integration window. The effectiveness of this cue depended on the temporal proximity between corresponding auditory and visual streams, but it was not specially enhanced when the streams were physically synchronous. The data suggested that correspondence perception followed the pattern of events over time, and not the absolute passage of time. Further, we found that the structure of the temporal pattern was important for correspondence detection. Counterintuitively, predictable, rhythmic event streams were harder to match crossmodally than stochastic, irregular streams. These results can be considered in terms of the information carried by different kinds of temporal structures.

Oral Session 5: Other

4:50 – 5:10

'When birds of a feather flock together': Synesthetic correspondences modulate audiovisual integration in non-synesthetes

Cesare Valerio Parise, Charles Spence

University of Oxford

Synesthesia is a condition in which the stimulation of one sensory modality elicits an additional experience, often in a different (i.e., unstimulated) sense. Although only a small proportion of the population is synesthetic, there is growing evidence to suggest that neurocognitively-normal individuals also experience some form of synesthetic association between the stimuli presented to different sensory modalities (i.e., between auditory pitch and visual size, where lower frequency tones are associated with large objects and higher frequency tones with small objects). While previous research has highlighted crossmodal interactions between synesthetically corresponding dimensions, the possible role of synesthetic associations in multisensory integration has not been considered previously. Here we investigate the effects of synesthetic associations by presenting pairs of temporally asynchronous or spatially discrepant visual and auditory stimuli that were either synesthetically matched or mismatched. In a series of three psychophysical experiments, involving unspeeded two alternatives forced-choice discrimination tasks, participants reported the relative temporal order of presentation or the relative spatial locations of the two stimuli. The results showed that the reliability of non-synesthetic participants' estimates of both audiovisual temporal asynchrony and spatial discrepancy were lower for pairs of synesthetically matched (i.e. high-pitched tones and small visual stimuli) as compared to synesthetically mismatched audiovisual (i.e. high-pitched tones and large visual stimuli) stimuli. Recent studies of multisensory integration have shown that the reduced reliability of perceptual estimates regarding intersensory conflicts constitutes the marker of a stronger coupling between the unisensory signals. These results therefore indicate a stronger coupling between synesthetically matched vs. mismatched stimuli and provide the first psychophysical evidence that synesthetic congruency can promote multisensory integration. Synesthetic crossmodal correspondences therefore appear to play a crucial (if unacknowledged) role in the multisensory integration of auditory and visual information.

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Oral Session 5: Other

5:10 – 5:30

Speech Motor Learning Modifies Speech Perception Psychophysics / Experimental Psychology

Sazzad M Nasir [1], David J Ostry [1, 2]

[1]Department of Psychology, McGill University, [2]Haskins Laboratories

Abstract As babies learn to talk, they form a link between what they hear and what they produce. In the process of speech acquisition, there is an apparent auditory perceptual bias in that babies, very early in life, are exposed to a plethora of speech sounds that play a crucial role in guiding the speech movements they are going to make. In this way, one sensory modality (audition) that will be involved in speech production presumably dominates speech motor learning and shapes the required patterns of the other sensory input (somatosensory) that is involved in the speech learning process. However, this relationship may not be unidirectional. In fact, it may be the case that auditory perception is modified over the course of speech motor learning. In this presentation, we report a test of this hypothesis. We tested 23 subjects who performed a speech perceptual test both before and after a related speech motor learning task. As a control, another 21 subjects performed exactly the same auditory task without the intervening speech learning procedure. In the perceptual identification test, each subject listened to an auditory stimulus that was chosen at random from a 10 step continuum between head and had and was required to indicate whether the presented item sounded more like head or like had. In this way, we were able to estimate the perceptual cross-over point between head and had and any potential perceptual changes associated with motor learning. In the accompanying speech learning procedure, a robotic device was used to alter speech movements, and in particular somatosensory feedback, by delivering velocity dependent loads to the jaw during speech production. These same mechanical loads had no effect on speech acoustical patterns during learning. With training subjects corrected for load, such that the motion path and presumably the associated somatosensory input approached that normally experienced under no-load conditions. A consistent pattern of perceptual change was observed for 17 of the 23 subjects that adapted to the mechanical load. The change in perceptual threshold following the learning task was significantly different than that observed among control subjects who performed two consecutive identification tasks but in the absence of motor learning. The control/non-adapted subjects did not show any net perceptual change. Further, the amount of perceptual changes among the adapted subjects was correlated with the amount of adaptation. These results are consistent with the view that speech motor learning modifies auditory perception.

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Oral Session 5: Other

5:30– 5:50

Influence of Visual Stimuli on Auditory Apparent Motion Perception

Thorsten Kluss [1], Niclas Schult [2], Christoph Zetzsche [3], Manfred Fahle [4], Kerstin Schill [5]

[1]Human Neurobiology, Bremen University; Cognitive Neuroinformatics, University of Bremen, [2]Cognitive Neuroinformatics, University of Bremen, [3]Cognitive Neuroinformatics, University of Bremen, [4]Human Neurobiology, Bremen University, [5]Cognitive Neuroinformatics, University of Bremen

We conducted behavioral experiments in which we investigated the influence of visual stimuli on auditory apparent motion (AAM) perception. Successive presentation of discrete auditory stimuli can induce the impression of a single moving stimulus. The quality of the perceived motion depends primarily on the Interstimulus Onset Interval (ISOI): Short ISOIs usually lead to the perception of a continuous motion at constant velocity, whereas longer ISOIs are perceived as broken, interrupted motion or even as a succession of discrete auditory events.

We investigated whether, and to which extent, the temporal threshold (i.e., the ISOI that determines the quality of AAM perception), is influenced by the presentation of visual stimuli which were temporally and spatially aligned between the auditory stimuli. In other words, visual stimuli were systematically added to fill the temporal and spatial gaps of the discretized auditory trajectory. The results of this coherent-bimodal condition were compared to a unimodal control condition in which only auditory stimuli were presented without any additional visual stimuli. In a second noncoherent-bimodal control condition, visual stimuli at random positions were added to each AAM sequence in order to assess whether the mere presence of visual stimuli may cause an alteration of the threshold due to attentional mechanisms.

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The experimental setup consisted of 31 loudspeakers (Sennheiser HD201) arranged in a semicircle (radius 115 cm) with 31 light emitting diodes (LEDs) mounted in the middle of each speaker cone. AAM sequences were presented in four variations using different numbers of speakers or nodes of the apparent trajectory. During the experiment the ISOI was varied from 0 – 400ms. The participants' task was to listen to the auditory stimuli (amplitude modulated white-noise) and categorize their perception of each stimulus sequence into one of four categories: (1) simultaneous presentation, (2) continuous motion, (3) broken motion and (4) succession. Each of the 17 subjects participated in the experimental condition (coherent-bimodal), control condition 1 (auditory), as well as control condition 2 (noncoherent-bimodal).

We found a facilitation of auditory apparent motion perception by systematically adding visual stimuli to the discretized auditory trajectory. Coherent-bimodal presentation led to a significant increase of the temporal threshold up to which continuous motion was perceived in comparison to the unimodal control condition, whereas no change of the threshold ISOI was found under the noncoherent-bimodal control condition. We interpret these results as evidence for audio-visual integration mechanisms in movement perception and assume a common bimodal representation of movement. This interpretation is corroborated by the assumption that audiovisual stimuli are mapped onto a common spatial reference frame within the neural system, as indicated by neurophysiological research and is consistent with findings of our earlier investigations on audio-visual integration mechanisms[1].

[1] Hofbauer, M., Wuerger, M., Meyer, G., Roehrbein, Florian, Schill, Kerstin and Zetzsche, Christoph, Catching audiovisual mice: Predicting the arrival time of audio-visual motion signals (2004), in: Cognitive, Affective and Behavioral Neuroscience, 4:2(241--250)

DAY 4 - THURSDAY

Oral Session 5: Other

5:50 – 6:10

The number and precision of neural timing processes underlying duration perception in vision and audition, estimated using the "equivalent noise" paradigm

David Alais, Joel Cooper
University of Sydney

These experiments explore duration perception in vision and audition to find the level of internal noise associated with time perception and the number of samples pooled into a duration estimate. Duration increment thresholds were measured for standard durations of 100,200,400,800 & 1600ms. A spatially distributed array of four LEDs (or loudspeakers) emitted visual (or auditory) signals to define a temporal duration. Randomly staggering signal onsets/offsets added variance (or 'noise') to the duration around a standard mean. Increment thresholds for each standard were measured for various temporal noise levels. Threshold change with added duration noise was modeled to estimate the level of internal duration noise and the number of samples being pooled in duration perception. This "equivalent noise" approach estimates internal noise (i.e., thresholds increase when added external noise exceeds internal neural noise) and the number of samples averaged into a single duration estimate (the slope of threshold change vs. added noise once internal noise is overcome). Data for vision and audition were similar. Discrimination thresholds increased with the standard duration (Weber fraction □ 15%). Importantly, once external noise exceeded internal noise, thresholds increase in proportion with added noise. This suggests a single timing process with no possibility for pooling estimates to deal with noise. Audiovisual experiments suggest this timing process is supramodal, as performance for visual (or auditory) signals was no better than a mixture of visual and auditory signals. In both modalities, Weber fractions for duration perception with multiple stimuli are relatively poor, reflected by relatively high levels of estimated internal noise. Once added noise exceeds internal noise, discrimination thresholds increase approximately in proportion to added noise. If multiple timers existed, averaging could be used to overcome external noise. The failure to find this suggests the visual and auditory systems cannot access multiple estimates of duration. Overall, the data suggest a single and relatively imprecise supramodal timing process.

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