NCM 22nd Annual Meeting

HILTON MOLINO STUCKY | VENICE, ITALY

Society for the
Neural Control of Movement

NCM

Satellite Meeting
April 22 – 23, 2012

22nd Annual Meeting
April 23 – 28, 2012

Society for the Neural Control of Movement | **www.ncm-society.org**

2012 At-A-Glance Satellite and Annual Conference Schedule

Society for the Neural Control of Movement

NCM

Hilton Molino Stucky, Venice, Italy

Sunday 22-Apr
Arrivals, Free Time, Excursions
- Satellite Registration (17:00 - 19:00)
- Satellite Dinner *in honor of* Professor Jose Maria Delgado Garcia (19:00 - 21:00)

Monday 23-Apr
- Registration /Information Desk Open
- Satellite Registration
- Satellite Meeting (8:30 - 17:30)
- Conference Registration (17:00 - 19:00)
- Opening Dinner (19:00 - 21:00)

Tuesday 24-Apr
- Registration /Information Desk Open
- Exhibits on Display
- Posters on Display (Session 1)
- Session 1 Panel SCHIEBER (8:00 - 10:15)
- Break (10:15 - 10:45)
- Session 2 Panel SABES (10:45 - 13:00)
- Poster Session 1a and Lunch (13:00 - 15:00)
- Session 3 Panel AZIM (15:00 - 17:15)
- Free Time and/or Excursions

Wednesday 25-Apr
- Registration /Information Desk Open
- Exhibits on Display
- Posters on Display (Session 1)
- Session 4 Panel FLASH (8:00 - 10:15)
- Break (10:15 - 10:45)
- Session 5 Individual Presentations (10:45 - 12:45)
- Poster Session 1b and Lunch (12:45 - 14:30)
- Session 6 Panel GRIBBLE (14:30 - 16:00)
- Session 7 Individual Presentations (16:00 - 17:20)
- Free Time and/or Excursions

Thursday 26-Apr
- Registration /Information Desk Open
- Exhibits on Display
- Session 8 Panel POZZO (8:00 - 10:15)
- Break (10:15 - 10:45)
- Session 9 Individual Presentations (10:45 - 12:05)
- Business Meeting (12:05 - 13:00)
- Free Time and/or Excursions
- *NCM Special Excursion* Private Evening of St. Mark's Church (19:45 - 21:15)

Friday 27-Apr
- Registration /Information Desk Open
- Exhibits on Display
- Posters on Display (Session 2)
- Session 10 Panel SUMINSKI (8:00 - 10:15)
- Break (10:15 - 10:45)
- Session 11 Individual Presentations (10:45 - 12:45)
- Poster Session 2a and Lunch (12:45 - 15:00)
- Session 12 Individual Presentations (15:00 - 17:00)
- Free Time and/or Excursions

Saturday 28-Apr
- Registration /Information Desk Open
- Exhibits on Display
- Posters on Display (Session 2)
- Session 13 Panel KRAKAUER (8:00 - 10:15)
- Break (10:15 - 10:45)
- Session 14 Panel BURDET (10:45 - 12:15)
- Poster Session 2b and Lunch (12:15 - 14:00)
- Session 15 BIZZI (14:00 - 15:00)
- Free Time and/or Excursions

Sunday 29-Apr
Departures, Free Time, Excursions

Time: 8:00, 8:15, 8:30, 8:45, 9:00, 9:15, 9:30, 9:45, 10:00, 10:15, 10:30, 10:45, 11:00, 11:15, 11:30, 11:45, 12:00, 12:15, 12:30, 12:45, 13:00, 13:15, 13:30, 13:45, 14:00, 14:15, 14:30, 14:45, 15:00, 15:15, 15:30, 15:45, 16:00, 16:15, 16:30, 16:45, 17:00, 17:15, 17:30, 17:45, 18:00, 18:15, 18:30, 18:45, 19:00, 19:15, 19:30, 19:45, 20:00, 20:15, 20:30, 20:45, 21:00, 21:15, 21:30, 21:45, 22:00, 22:15, 22:30

Program Contents

About NCM

The Society for the Neural Control of Movement (NCM) is an international community of scientists, clinician-investigators and students all engaged in research whose common goal is to understand how the brain controls movement.

NCM was conceived in 1990 by Barry Peterson. With an initial leadership team that also included Peter Strick and Marjorie Anderson, NCM was formally established to bring together scientists seeking to understand the neural mechanisms that guide meaningful activities of daily life, primarily through the brain's control of the eyes, head, trunk, and limbs. Early members consisted largely of systems neurophysiologists, behavioral, computational and theoretical neurobiologists, and clinician-investigators interested in disorders of motor function.

From the outset the goal of NCM was to provide a useful gathering of investigators in an informal and casual setting to present and discuss where we are in a diverse and complex field, where we should be going and how we might best proceed as a community with multiple perspectives and approaches. The meeting was to be unique in style, such that sessions were formulated and proposed by small groups of members themselves and geared to inform the larger attending community through focused presentations integrated into themes. Sessions would change in content with each yearly meeting.

The inaugural NCM Conference took place in April, 1991 on Marcos Island, Florida, with roughly 140 attendees. The success of the initial years promoted longevity and expansion of NCM and its conference, both in attendance (now over 300, with membership over 400) and the breadth of scientific content. Sessions cover all levels of inquiry--from perception to genetic expression, and from whole organism to intracellular function, while also including computational and theoretical approaches. This highly regarded conference continues to meet in desirable, family-friendly locations in late April or early May every year.

Welcome

To the Society for the Neural Control of Movement
22nd Annual Meeting

Welcome to the 22nd Annual Conference of the Society for the Neural Control of Movement, and welcome a truly unique location for us -- Venice, Italy. This is our 'once per decade indulgence' in holding our meeting in a particularly unusual setting. I and the Board are delighted to witness so many members attending this year. This is surely testimony to the vibrancy of the Society and our yearly meeting. In these difficult times, in the midst of an international recession, you have voted 'with your feet' and expressed an ongoing commitment to NCM, its community of scientists, and to the bond that brings us together to share our work as well as our many interactions. NCM continues to attract new and established investigators alike, and presentations across a range of formats, all tuned to our signature collegiality. It is also delightful to witness so many accompanying guests, spouses, and families that will undoubtedly share a memorable week with us. All of this makes a difference, and I thank all of you for your presence and your engagement.

Gary Paige, President

As always, NCM succeeds through an evolving slate of topics which in turn, depends upon new members and contributors that include new and young investigators. Roughly a quarter of our meeting attendance constitutes students in recent years. Our scholarship program continues its strong showing, though as expected, the challenge of Venice has prevented some of our regulars from directly participating this year. Thanks to the ever-relentless efforts of Terry Sanger, our Development Officer,

we nevertheless exceeded expectations for scholarship support.

On another note, we continue to explore means of honing and improving the meeting structure. Doug Munoz has implemented an outstanding program this year. This year you will notice more individual oral-presentation sessions than in the past, and some are parsed topically as well. Our social meal this year is uniquely blended, since a classic Hilton-style breakfast comes with the room while we continue to enjoy the combination of a grazing lunch with poster viewing as implemented last year. This also provides flexible time to visit our sponsors' exhibits, and I encourage all to do so.

Finally, we continue to enjoy and benefit from our collaboration with De Armond Management Ltd. The support throughout the year continues to improve the Society's affairs and operations, including our evolving web site and services to all members. Roz, Laurie and Marischal will be available to you throughout the conference to ensure the support you need and to enhance the quality of your experience during the conference.

I, my fellow Officers, and the NCM Board welcome all of you to Venice and to a stellar conference for 2012.

Cordially,

Gary Paige
President

NCM Leadership

Elected members govern the Society for the Neural Control of Movement. These members comprise the Board of Directors who in turn elects Officers that comprise the Executive Committee. The Society's Bylaws govern how the Board manages the Society.

Officers and Board members are elected for three-year terms and may be re-elected to one additional contiguous term. The current Board comprises the following Officers and Directors:

Doug Munoz   *Henrietta L. Galiana*   *Terry Sanger*

Officers (Executive Committee)

President & Conference Chair
Gary D. Paige (president@ncm-society.org)

Vice President & Scientific Chair
Doug Munoz (vpprogram@ncm-society.org)

Treasurer & Secretary
Henrietta L. Galiana (treasurer@ncm-society.org)

Development Officer
Terry Sanger (sponsor@ncm-society.org)

Board Members

Name	Institution	Country	Term
Andrea d'Avella[2]	Fondazione Santa Lucia	Italy	2012 - 2015
Chris Miall[2]	University of Birmingham	UK	2012 - 2015
Philip Sabes[1]	University of California San Francisco	USA	2009 - 2012
James Lackner[1]	Brandeis University	USA	2009 - 2012
Tim Ebner[1]	University of Minnesota	USA	2010 - 2013
Lee Miller[1]	Northwestern University	USA	2010 - 2013
John Krakauer[1]	Columbia University	USA	2010 - 2013
Kathy Cullen[1]	McGill University	Canada	2010 - 2013
Amy Bastian[2]	Kennedy Krieger Institute	USA	2011 - 2014
Randy Flanagan[2]	Queens University	Canada	2011 - 2014
Paul Cisek[2]	University of Montreal	Canada	2011 - 2014
Jeroen Smeets[1]	VU University Amsterdam	Netherlands	2011 - 2014

Incoming Board Members

The following members will begin their term in May, 2012.

Andrew Pruszynski[1]	Umea University	Sweden	2012 - 2015
Stephen Scott[1]	Queens University	Canada	2012 - 201

[1] *Serving first 3 year term*   [2] *Serving second 3 year term*

Board Service

Nominations for NCM Board service open in September. Nominations must come from members in good standing, and only members are invited to stand for election. To learn more about Board service or if you are interested in serving on the NCM Board, please discuss your interest with one of NCM's Board members or Officers, or send an email to Treasurer@NCM-Society.org.

NCM Administration

Association Secretariat & Conference Management
(management@ncm-society.org)

De Armond Management Ltd.
Roz Beddall
Laurie De Armond
Marischal De Armond

Administrative Assistant
Kelly Moore, Queens University

Membership Information

Society for the
Neural Control of Movement

NCM

NCM membership is open to all scientists, principal investigators and students from around the world, pursuing research whose goal is to understand how the brain controls movement. Memberships are valid September 1 through August 31 each year.

NCM membership includes the following benefits:
- Opportunity to submit proposals and abstracts for sessions at the Annual Meeting
- Opportunity to submit proposals for satellite meetings
- Opportunity to register for Annual NCM Meetings at reduced registration rates

- Access to the member resource database and other members' web services
- Professional development and networking
- Ability to post job opportunities
- Access and ability to respond directly to job opportunity postings
- Access to online NCM resources and Annual Meeting proceedings
- Access to scholarships (Grad Students and Post Docs)
- Opportunity to vote in Annual Elections of NCM Board members
- Opportunity to stand for election to, and serve on, the NCM Board of Directors
- Regular email updates and notices

To become an NCM Member please visit us at the registration desk today.

General Information

Meeting Venue

Hilton Molino Stucky
Giudecca 810, 30133
Venice, Italy

The conference venue is the Hilton Molino Stucky. All conference sessions will take place in this location.

Satellite Meeting
Satellite Meeting registration fees include access to the full day meeting with refreshment breaks and a buffet lunch. If you are staying at the Hilton Molino Stucky, a full buffet breakfast is included in your room rate.

Annual Meeting
Annual Conference registration fees include access to all sessions including panel, individual and poster sessions. Registration also includes daily refreshment breaks, grazing lunches and the Opening Dinner. If you are staying at the Hilton Molino Stucky, a full buffet breakfast is included in your room rate.

Additional Tickets
Tickets can be purchased separately for your guests and/or children for all conference excursions, the Professor Garcia Honoring Dinner and the Opening Dinner. If you are not staying at the Hilton Molino Stucky, breakfast vouchers for the El San Juan breakfast buffet can be purchased separately for all registrants and their guests. These additional tickets can only be purchased from the staff at NCM's Registration Desk.

Name Badges
Your name badge is your admission ticket to the conference sessions, coffee breaks, meals, and Opening Dinner. Please wear it at all times. At the end of the Conference we ask that you recycle your name badge in one of the name badge recycling stations that will be set out, or leave it at the Registration Desk.

To help identify and mentor our future investigators, student delegates have red edged badges. All other delegates have clear badges. NCM Officers and Board Members, Exhibitors and Staff will be identified by appropriate ribbons.

Dress Code
Dress is casual for all NCM meetings and social events.

Registration and Information Desk Hours
The NCM Registration and Information Desk, located in the foyer, will be open during the following dates and times:

Monday	April 23	8:00 – 15:00
		17:00 – 19:00
Tuesday	April 24	8:00 – 15:00
Wednesday	April 25	8:00 – 15:00
Thursday	April 26	8:00 – 13:00
Friday	April 27	8:00 – 15:00
Saturday	April 28	8:00 – 15:00

If you need assistance during the meeting, please visit the Registration Desk.

Message Board
For your convenience, a Message Board will be located near the Registration Desk. Feel free to leave messages of interest to other meeting participants.

Poster Information

Set-Up / Removal
There are two Poster Sessions during the Meeting and posters have been allocated to either one of the sessions based on poster themes. Poster presenters must set-up and remove their posters during the following times.

Session 1
Set-up: Tuesday, April 24, between 7:00 and 10:15

Remove: Wednesday, April 25, between 17:20 and 18:00

Session 2
Set-up: Friday, April 27, between 7:00 and 10:15

Remove: Saturday, April 28, between 15:00 and 16:00

Information on Poster Authors (Lead), Poster Numbers and Poster Titles begins on page 34. For a complete copy of all the poster abstracts, a limited supply of printed abstracts is available for purchase at the Registration Desk. Digital copies can be downloaded from the Member Only section of the NCM Website.

Easy reference Poster Floor Plans for each session can be found on the inside back cover of this program.

Staff
NCM staff from De Armond Management can be identified by ribbons on their name badges. Feel free to ask any one of our staff for assistance.

Daycare Services
The conference hotel provides Child care services at a cost of 25 Euros per hour. If you are interested in this service, please visit the Hotel Concierge located at the Hotel Front Desk.

Internet Services
NCM has arranged some excellent package deals for internet access throughout the Hilton (ie bedroom, meeting space and public space). Should you wish to access the internet during the conference, you must purchase one of the internet packages. Please note, these internet connections are IP specific, so are only accessible to 1 computer. If you are interested in purchasing an internet package, please inquire at the Registration Desk.

No Smoking Policy
Aside from a few bedrooms on the third floor, smoking is not permitted inside the Hilton Molino Stucky. Smoking areas are located outside the building.

Conference Venue Floor Plan

Foyer

Venetian Ballroom

Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

Foyer

Foyer

Elevators

Entrance

Molino Stucky Hilton
Venice
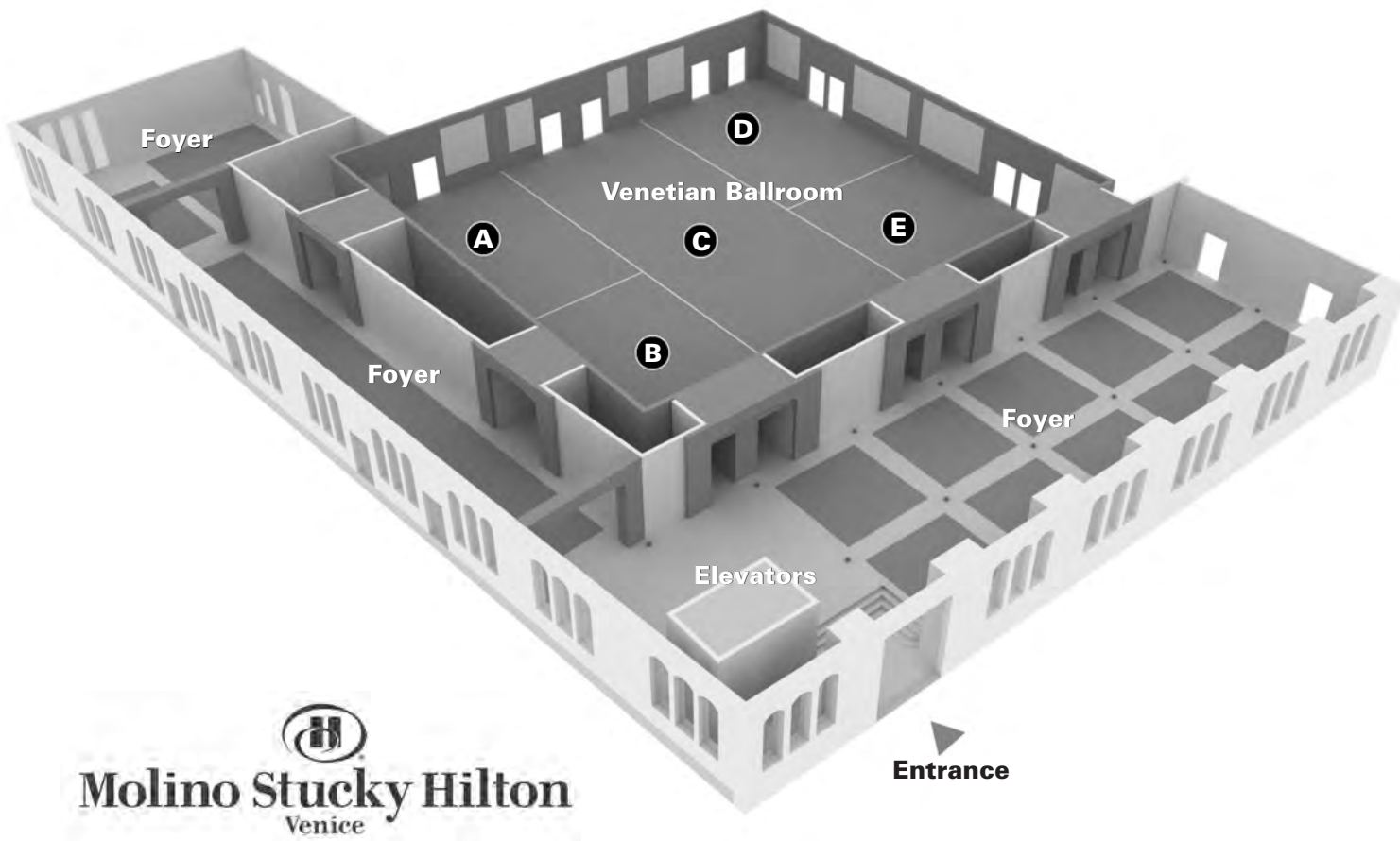
Special Meetings & Events

Sunday, April 22 19:00 - 21:00
Satellite Dinner in honor of Professor Jose Maria Delgado Garcia
Location: Molino Restaurant

Monday, April 23 19:00 - 21:00
Opening Dinner
Location: Venetian Ballroom

Thursday, April 26 12:05 - 13:00
NCM Business Meeting
Location: Venetian Ballroom

Thursday, April 26   19:45 - 21:15
NCM Special Excursion
Private Evening of St. Mark's Church
Location: St. Mark's Square, in front of Church

Conference Excursions

We invite you to take advantage of your visit to Venice by exploring the city on one of our special NCM excursions. Your time in Venice will be so much more memorable as a result.

A limited number of spaces remain for our NCM excursions. A list of the trips can be found below. If you are interested in joining one of these trips, please inquire at the Registration Desk.

NCM Special

Private Evening of St. Mark's Church

(approx 1.5 hrs)
In the course of this unforgettable visit, the church will be open after the evening mass especially and only for NCM, and the wonderful mosaics interior shall be revealed in all its splendour with the aid of a special illumination system. If you are only able to partake in one special excursion while in Venice, this should be the one you choose...

Cost / person: $30

Introducing Venice (2.0 hrs)

This is a pleasant walk to acquaint you with this unusual city. As we stroll through backstreets, across bridges and canals, you will learn about the city and its origins; the whys, wherefores and hows related to its construction "on water", and; anecdotes and, aspects of present and past Venice. We shall pass by Campo Santo Stefano, Campo Sant'Angelo, the beautiful Snail Staircase of Palazzo Contarini, and the Rialto Bridge and finally reach St. Mark's Square, the very heart of the city, where the most important monuments still stand in all their magnificence: the Ducal Palace, the Campanile, the Marciana Library, the Procuratie, the Clock Tower and St. Mark's Church...

Cost / person: $22.50

Cruising the Grand Canal - Venice Seen From the Water (1.0 hrs)

There is no doubt that Venice was built to be seen from the water where it is at its most spectacular and magnificent. This is a complete itinerary via private taxi around and through the lagoon city for those who want to enjoy a unique experience, discovering the charm and silence of narrow canals immersed in shadow, observe the silhouettes of ancient rooftops against limpid skies; the itinerary meanders through vibrant neighbourhoods, under bridges and past squares, a glimpse of secret gardens; glide down the Grand Canal with the centuries-old palaces on either side, the air full of the cries of gondoliers; soak up the sun on the open lagoon… A magic synthesis to the rhythm of the waves! **Cost / person: $37.50**

Deep Venice: The Scuola of San Rocco and the Frari Church (approx 3.0 hrs)

Venice and its 118 little islands connected by approximately 400 bridges is undoubtedly a very special and unique city. You will therefore surely enjoy this off-the-beaten track stroll through narrow alleyways and across bridges and side canals to discover the beauty and the very structure of the city. You will learn about the city's origins, how its magnificent palaces were constructed "on water", as well as other interesting aspects of present and past Venice...

Cost / person: $51

The Accademia Gallery (2.0 hrs)

If you love or even simply appreciate painting you should not miss this visit. The Accademia Gallery in fact hosts a distinguished and representative collection of paintings by Venetian artists, from 14th C to 18th C. It's the most important museum of Venetian painting with masterpieces by Paolo Veneziano, Gentile and Giovanni Bellini, Carpaccio, Giorgione, Titian, Tintoretto, Veronese, Tiepolo that well testify to the contribution and the achievements of the Venice School of Painting... **Cost / person: $36**

The Guggenheim Collection (2.0 hrs)

If you are fond of 20th century art, you can't miss a tour to the Peggy Guggenheim Collection, one of the most important museums in Italy for European and American modern art. It is located in Peggy's former home, Palazzo Venier dei Leoni, a beautiful building from the 18th C on the Grand Canal. Peggy Guggenheim purchased it in 1948 and lived there until she died in 1979. The museum was opened in 1980 and exhibits Peggy Guggenheim's personal collection of European and American 20th century art, as well as masterpieces from the Gianni Mattioli Collection, the Nasher Sculpture Garden, and temporary exhibitions. The Peggy Guggenheim Collection belongs to the Solomon R. Guggenheim Foundation, which also operates the Solomon R. Guggenheim Museum, New York, the Guggenheim Museum Bilbao, and the Deutsche Guggenheim, Berlin... **Cost / person: $42**

Punta Della Dogana - Contemporary Art and Architecture (2.0 hrs)

In 2009 Tadao Ando, one of the best known and most popular architects in the world, completed the restoration of the Punta della Dogana, an ancient building which had formerly sheltered the custom houses of the Republic of Venice. Ando transformed this building into a new centre of contemporary art, exhibiting works from the François Pinault Collection. The building is located in one of the most extraordinary sites in Venice, at the tip of the Dorsoduro district, splitting Canal Grande from Canale della Giudecca. Thanks to Ando's vision, every tour of the Punta della Dogana is a unique experience. The use of windows and gallery spaces provides a dramatic and astonishing effect... **Cost / person: $46.50**

Murano and Glass Blowing (approx 2.0 hrs)

In the middle-ages Venice became the leading centre of glass manufacturing. The small island of Murano –only 20 mins from Venice - was the site where this industry flourished. To limit the threat of devastating fires in the city all furnaces were located on Murano. Today the secrets and skills of glass making have spread worldwide, and yet Murano still holds its reputation high. There is nothing like visiting a furnace and standing in front of a glass master blowing, rolling, heating, and shaping a hot glass glob into a wonderful piece of art, to fully appreciate the brilliance of

this workmanship. After the demonstration you are obviously welcome to visit the factory showrooms to view an incredible display of glass art pieces – it is equal to a museum! **Cost / person: $27**

Exploring the Lagoon: Murano, Burano and Torcello (4.0 hrs)

Venice lies in the centre of a vast lagoon that stretches for about 30 miles from north to south, studded by numerous small islands, mostly deserted. This amazing environment is what drove the Venetians to establish their city here, a perfectly secure and inaccessible little world. Enjoy the beauty and calm of this unspoiled waterscape on a private water taxi and visit the 3 most important little islands situated in the northern section of the lagoon: Murano is where you can enjoy a demonstration of glass blowing in a local furnace, Burano is a quaint and colourful fisherman island and Torcello hosts an awesome cathedral constructed in 1008, the oldest monument in the lagoon...

Cost / person: $82.50

A Gondola Ride (35 mins)

The gondola is the queen of all traditional row-boats in Venice and is the quintessential Venetian experience. It's always existed and until 60 years ago it was the main means of transport. A gondola ride is a beautiful and relaxing experience that shouldn't be missed. You will enjoy a ride through the small canals accompanied by a gondolier, his stories and perhaps some songs. Each gondola accommodates up to 6 individuals and each excursion lasts 35 minutes. You pick a preferred time and your guaranteed reservation will be made. You will then be given a voucher and a map showing where you can collect your ride and embark on our most memorable of Venice experiences...

Cost / person: $105 for trips completing by 7:00 pm (suggested last trip 6:00 pm); $125 for trips starting after 7:00 pm

Future Meetings

2013 Annual Meeting and Satellite

We are pleased to announce the 2013 Annual Meeting will take place, once again, at the El San Juan Hotel & Casino, the Waldorf Astoria Collection, in San Juan on the beautiful island of Puerto Rico. Please plan to attend the 23rd Annual Meeting in San Juan, Puerto Rico.

The Annual Meeting will take place April 16 – 21, 2013 at the El San Juan Hotel & Casino, located in the fashionable Isla Verde district, only 10 minutes from San Juan's International Airport. The charming and stunning El San Juan hotel is nestled along the most beautiful beach on the island and surrounded by 15 lush acres of landscaped grounds - perfectly blending tropical splendor with old-world sophistication. This is one meeting you will not want to miss.

Plan now to attend. Information about the meeting, the location and the hotel (including reservation information) will be available on the NCM Website shortly.

Satellite Meetings

NCM's Board welcomes suggestions for one- or two-day Satellite Meetings in conjunction with future Annual Meetings. Please discuss your ideas with NCM Board Members to formulate an early plan/proposal, and bring this to the NCM President for further consideration (email: President@NCM-Society.org).

We are currently soliciting proposals for a 2013 Satellite Meeting. Formal proposals can be submitted to the President and must include:

• One page description covering motivation, goals, timeliness and organizational plan

• Second page with a tentative schedule of session topics, and preliminary leaders and/or participants if available

• A proposal for funding is encouraged (eg NIH R13, NSF, other)

Keynote Speakers

NCM provides the opportunity for members to suggest prominent colleagues in the field of neuroscience who would be suitable candidates to provide a Keynote Address during an Annual Meeting. The Keynote is an invited lecture delivered by a prominent colleague whose contributions to neuroscience are widely acknowledged. Individuals and topics outside the normal NCM community are encouraged.

If you wish to recommend a colleague as a future keynote presenter please discuss with an NCM Board Member or Officer or send an email to President@NCM-Society.org.

NCM History

Since 1991 NCM's annual meetings have provided a forum for leading edge research, scholarly debate, the interchange of ideas, and a platform for many exceptional established and emerging researchers in the field of Neural Science. We are proud that this has all been accomplished in some of the nicest destinations in the world. Our history is strong and our future is bright.

Meeting	Dates	City	Country	Hotel
21st Annual Meeting*	April 26 – 30, 2011	San Juan, Puerto Rico	USA	El San Juan Hotel & Casino
20th Annual Meeting*	April 20 – 25, 2010	Naples, Florida	USA	Naples Beach Hotel & Golf Club
19th Annual Meeting*	April 28 – May 3, 2009	Waikoloa, Hawaii	USA	Waikoloa Beach Marriott Resort & Spa
18th Annual Meeting	April 29 – May 4, 2008	Naples, FLA	USA	Naples Beach Hotel & Golf Club
17th Annual Meeting*	March 25 – April 1, 2007	Seville	Spain	Melia Sevilla
16th Annual Meeting*	April 30 – May 7, 2006	Key Biscayne, FLA	USA	Sonesta Beach Resort
15th Annual Meeting	April 12 – 17, 2005	Key Biscayne, FLA	USA	Sonesta Beach Resort
14th Annual Meeting*	March 25 – April 3, 2004	Sitges	Spain	Melia Sitges
13th Annual Meeting	April 22 – 27, 2003	Santa Barbara, CA	USA	Fess Parker's Doubletree Resort
12th Annual Meeting*	April 14 – 21, 2002	Naples, FLA	USA	Naples Beach Hotel & Golf Club
11th Annual Meeting	March 25 – 30, 2001	Seville	Spain	Melia Sevilla
10th Annual Meeting	April 9 – 17, 2000	Key West, FLA	USA	Wyndham Casa Marina Resort
9th Annual Meeting*	April 11 – 19, 1999	Kauai, Hawaii	USA	Princeville Resort
8th Annual Meeting	April 14 – 22, 1998	Key West, FLA	USA	Marriott Casa Marina Resort
7th Annual Meeting*	April 8 – 16, 1997	Cozumel	Mexico	Presidente Intercontinental
6th Annual Meeting	Apri 16 – 21, 1996	Marco Island, FLA	USA	Radisson Suite Beach Resort
5th Annual Meeting	April 18 – 25, 1995	Key West, FLA	USA	Marriott Casa Marina Resort
4th Annual Meeting*	April 13 – 22, 1994	Maui, Hawaii	USA	Maui Marriott Resort (Lahaina)
3rd Annual Meeting	April 13 – 18, 1993	Marco Island, FLA	USA	Radisson Suite Beach Resort
2nd Annual Meeting	April 21 – 26, 1992	Marco Island, FLA	USA	Radisson Suite Beach Resort
1st Annual Meeting	April 6 – 11, 1991	Marco Island, FLA	USA	Radisson Suite Beach Resort

indicates a Satellite Meeting was held in conjunction with the Annual Meeting

NCM Satellite Meeting – Program

NCM Satellite Meeting, Venice, Italy
April 22 – 23, 2012

Sensorimotor plasticity and learning: From bench to bedside

Organizers: Andrea d'Avella, Pierre Paul Vidal

Sunday, April 22

17:00 – 19:00   **Satellite registration**

19:00 – 21:00   **Dinner*** in Honor of Professor Jose Maria Delgado Garcia

           *Notes: This dinner is open to all (i.e. it is not necessary to attend the Satellite Meeting in order to attend the dinner). There is an additional cost for the dinner.

Monday, April 23

8:30 – 8:45   **Introduction**

           Robert Baker, New York University, USA
           Where we began and where we are now?

8:45 – 10:15   **Cerebellum and motor learning**

           Organizer: John Simpson, New York University, USA

           John Simpson
           The dark and light sides of floccular climbing fibers

           Vlastilav Bracha, Iowa State University, Ames, USA
           Cerebellar signals in eyeblink conditioning and the dark energy of the brain

           Ferdinando Rossi, University of Turin, Italy
           Structural plasticity and regulation of growth in the cerebellum

           Javier Medina, University of Pennsylvania, Philadelphia, USA
           Cerebellar signals for trial by trial adaptation during eyeblink conditioning in mice

           Christopher Yeo, UCL, London, England
           Consolidation of cerebellar motor memories

10:15 – 10:45   **Coffee break**

10:45 – 12:15   **Neural substrates underlying motor and associative learning**

           Organizer: Chris De Zeeuw, Erasmus University, Rotterdam, The Netherlands

           Chris De Zeeuw
           Phase Control in the Vestibulocerebellum

           Werner Graf, Howard University, Washington, USA
           Structure and function of motion perception and behavior

           Guy Cheron, Universite Libre de Bruxelles, Belgium
           Theta stimulation of the whisker pad induces cerebellar LTD in alert mice

           John Disterhoft, Northwestern University, Chicago, USA
           Forebrain encoding of trace eyeblink conditioning

           Yoshikazu Shinoda, Tokyo University, Japan
           Neural mechanisms of suppressing omnipause neurons at the onset of and during saccades

12:15 – 13:45   **Lunch**

Monday, April 23 *continued*

13:45 – 15:15 **Vestibular plasticity**

Organizer: Pierre–Paul Vidal, Rene Descartes University/CNRS, Paris, France

Kathy Cullen, McGill University, Montreal, Canada
Information transmission and detection thresholds in early vestibular processing: implications for the coding of self motion

Dora Angelaki, Baylor College of Medicine, Houston, USA
Spike count variability in vestibular neurons: implications for central vestibular processing and population decoding

Hans Straka, Ludwig Maximilians University Munich, Germany
Ontogenetic development of visuo vestibular reflexes in /Xenopus/

Pierre–Paul Vidal
Adaptation of intrinsic and synaptic properties of medial vestibular neurons during visual vestibular

15:15 – 15:45 **Coffee break**

15:45 – 17:15 **Motor synergies: development, adaptation, plasticity**

Organizer: Andrea d'Avella, Santa Lucia Foundation, Rome, Italy

Francesco Lacquaniti, University of Rome Tor Vergata, Italy
First baby steps and the development of locomotor patterns

Andrea d'Avella
Adaptation to virtual surgeries compatible and incompatible with muscle synergies

Vincent Cheung, MIT, Cambridge, USA
Effects of stroke severity and post stroke duration on the organization of upper limb muscle synergies

Lena Ting, Emory University and Georgia Institute of Technology, Atlanta, USA
Muscle synergies for assessment of neuromotor deficit and rehabilitation

17:15 – 17:30 **Conclusion**

Jose Maria Delgado Garcia, University Pablo de Olavide, Seville, Spain.

Annual Meeting Detailed Daily Program

All sessions held in the Venetian Ballroom C, D, and E. Posters will be located throughout the conference area.

DAY 1 **Monday, April 23**

8:00 – 8:30	Satellite Registration
8:30 – 17:30	Satellite Meeting
17:30 – 19:00	Conference Registration
19:00 – 21:00	Opening Dinner

DAY 2 **Tuesday, April 24**

8:00 – 10:15 **PANEL Session 1**

Rapid flexibility: Creating novel patterns for novel control
Organizer: M. Schieber   Participants: F. Mussa-Ivaldi, K. Mosier, A. Jackson

10:15 – 10:45 BREAK

10:45 – 13:00 **PANEL Session 2**

Variability and learning: chicken or egg?
Organizer: P. Sabes   Participants: R. van Beers, M. Brainard, M. Smith

13:00 – 15:00 **POSTER Session 1a**
LUNCH

15:00 – 17:15 **PANEL Session 3**

The comparative design of neural circuits for mammalian skilled forelimb movement
Organizer: E. Azim   Participants: T. Jessell, R. Lemon, M. Churchland, B. Alstermark

DAY 3 **Wednesday, April 25**

8:00 – 10:15 **PANEL Session 4**

Controlling movement in the octopus - from biological to robotic arms
Organizer: T. Flash   Participants: W. Kier, B. Hochner, D. Tsakiris, C. Laschi

10:15 – 10:45 BREAK

10:45 – 12:45 **INDIVIDUAL PRESENTATIONS I Session 5**

Control of gaze shifts in monkeys with vestibular prostheses
Participants: J. Phillips, L. Ling, T. Oxford, A. Nowack, C. Kaneko, A. Fuchs, S. Bierer, K. Nie, J. Rubinstein

Functional roles of commissural inhibition and excitation between the superior colliculi for control of saccades in relation to Listings law and the VOR
Participants: Y. Shinoda, M. Takahashi, Y. Sugiuchi

Fractal fluctuations in movement variability: Insights into motor learning
Participants: A. Wong, M. Shelhamer

Internal models for predictive saccades in a natural interception task
Participants: G. Diaz, J. Cooper, M. Hayhoe

An optimal control model of the compensatory eye movement system
Participants: M. Ginzburg, T. Sibindi, M. Frens, O. Donchin

Memory and prediction in cerebral cortex, basal ganglia and cerebellum
Participants: R. Scheidt, N. Salowitz, J. Zimbelman, A. Suminski, K. Mosier, J. Houk, L. Simo

12:45 – 14:30 **POSTER Session 1b**
LUNCH

14:30 – 16:00 **PANEL Session 6**

Non-linear musculoskeletal properties: blessing or burden for motor control?
Organizer: P. Gribble   Participants: K. van Soest, M. Bobbert, D. Kistemaker

16:00 – 17:20 **INDIVIDUAL PRESENTATIONS II Session 7**

Monkey premotor and motor cortex reflect the decision process and determine the commitment to initiate a reaching movement
Participants: D. Thura, P. Cisek

Dorsal parietal area 5 encodes reaching component in sequential arm movement
Participants: H. Cui, Y. Li

Evidence for plateau potentials in human subthalamic nucleus neurons in Parkinson's Disease
Participants: R. Brownstone, H. Hultborn

Impaired retention of visuomotor adaptation in Parkinson's disease, improved with cortical stimulation
Participants: R. Joundi, J. Brittain, M. Bogdanovic, T. Aziz, P. Brown, N. Jenkinson

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DAY 4   Thursday, April 26

8:00 – 10:15   **PANEL Session 8**
Neural mechanisms at the basis of action observation, motor simulation and action prediction: what have we learned in the past years?
Organizer: T. Pozzo   Participants: I. Domingues Vargas, V. della Maggiore, L. Fadiga, C. Papaxanthis

10:15 – 10:45   BREAK

10:45 – 12:05   **INDIVIDUAL PRESENTATIONS III Session 9**

Predicting and correcting human ataxia using a model of cerebellar functio
Participants: N. Bhanpuri, A. Okamura, Amy J Bastian

A stimulation approach to analyze the neural error signals cerebellum-dependent motor learning
Participants: J. Raymond, B. Nguyen-Vu, J. Rinaldi, R. Kimpo, C. Kim

Mapping lesions to abnormal arm kinematics during recovery from cerebellar stroke
Participants: H. J. Konczak, D. Timmann

Computational control of the conditioned eye blink reflex in rodents
Participants: R. Prueckl, A. Taub, R. Hogri, A. Magal, M. Mintz, C. Guge

12:05 – 13:00   BUSINESS MEETING

DAY 5   Friday, April 27

8:00 – 10:15   **PANEL Session 10**
The contribution of sensory signals in constructing brain-machine interfaces
Organizer: A. Suminski
Participants: S. Bensmaia, J. O'Doherty, K. Otto

10:15 – 10:45   BREAK

10:45 – 12:45   **INDIVIDUAL PRESENTATIONS IV Session 11**

Information processing in human tactile afferent neurons
Participants: A. Pruszynski, R. Johansson

Genetic dissection of the spinal circuit for hand dexterity in macaque monkeys
Participants: T. Isa, M. Kinoshita, R. Matsui, S. Kato, T. Hasegawa, H. Kasahara, K. Isa, A. Watakabe, T. Yamamori, Y. Nishimura, B. Alstermark, D. Watanabe, K. Kobayashi

Muscle activity during voluntary movement is generated and controlled by spinal interneurons that mediate proprioceptive reflex in awake, behaving monkey.
Participants: K. Seki, G. Kim, T. Takei

Reticulospinal contributions to coordinated finger movement: Evidence from startle
Participants: C. Honeycutt, M. Kharouta, E. Perreault

Spinal selection of modular elements: spinal motor planning evidence from combined neural and EMG analysis?
Participants: S. Giszter, C. Hart   *Continued next page*

Detailed Daily Program

INDIVIDUAL PRESENTATIONS IV Session 11 *Continued*

Optimal control of eye-head movements with changing head plant characteristics
Participants: S. Glasauer, M. Saglam, N. Lehnen

12:45 – 15:00   **POSTER Session 2a**
LUNCH

DAY 5   **Friday, April 27** *continued*

15:00 – 17:00   **INDIVIDUAL PRESENTATIONS V Session 12**

A novel computational approach helps explain and reconcile conflicting experimental findings on the neural control of arm endpoint stiffness
Participants: J. Inouye, F. Valero-Cuevas

Unmasking reflexive control of the arm reaching
Participants: S. Perfiliev, J. Wessberg

Somatosensory perceptual training changes sensorimotor networks in the resting brain
Participants: D. Ostry, S. Vahdat, M. Darainy

Cortical Foundations of Human Speech Production
Participants: K. Bouchard, N. Mesgarani, M. Babiak, K. Johnson, E. Chang

Preparatory fronto-occipital alpha phase and distributed cortical oscillations predict failures of cognitive control
Participants: B. Clementz, J. Hamm, K. Dyckman, J. McDowell

Functional connectivity of the frontal eye fields in humans and macaque monkeys investigated with resting-state fMR
Participants: S. Everling, R. Menon, J. Gati, R. Hutchison

DAY 6   **Saturday, April 28**

8:00 – 10:15   **PANEL Session 13**

Motor skill learning across model systems:cortical-subcortical interactions
Organizer: J. Krakauer   Participants: A. Haith, B. Olveczky, J. Carmena, R. Costa

10:15 – 10:45   BREAK

10:45 – 1:00   **PANEL Session 14**

Complex tasks with multiple solutions: A challenge for traditional motor control
Organizer: E. Burdet   Participants: D. Sternad, A. d'Avella, G. Gowrishankar

12:15 – 14:00   **POSTER Session 2b**
LUNCH

14:00 – 15:00   **KEYNOTE Session 15**
Emilio Bizzi

PANEL Session 1

Tuesday, April 24

8:00 – 10:15

Rapid flexibility: Creating novel patterns for novel control

Philip Sabes[1], Robert van Beers[2], Michael Brainard[1], Maurice Smith[3]

[1]University of California - San Francisco, [2]VU University Amsterdam, [3]Harvard University

Reflexes, pattern generators and muscle synergies contribute substantially to control of many movements across the animal phyla. The mammalian motor system, however, can readily create novel movements that enable successful interactions in previously un-experienced environments. The ability to generate such novel movements is perhaps most developed in the hands of primates, especially humans. What principles underlie the creation of such novel patterns of coordination? What parts of the nervous system participate? And how can outputs normally used for one purpose be re-combined for a new purpose? One key feature of a rapidly flexible motor control system may be a control level that has higher dimensionality than the output being controlled. Redundancy in the control space then provides numerous possible projections to the lower dimensional output from which a usable solution can be chosen rapidly and honed with practice. Our panel will examine the creation of novel coordination patterns in humans and monkeys, from voluntary finger movements to brain-computer interfaces, and from fMRI to EMG and single neuron activity. Mussa-Ivaldi will show that normal human subjects can learn to control a 2 degree-of-freedom interface with novel combinations of motion in multiple joints of the hand, and that spinal cord injured subjects can learn such control with remaining movements of their proximal upper extremities. Mosier will describe fMRI studies of changes in brain activation as subjects learn such novel patterns of motor control. Jackson will describe how human subjects can generate arbitrary patterns of hand muscle EMG activity when controlling a myoelectric interface. He will show how new muscle synergies result from adaptation of both feed-forward drive through divergent corticospinal projections and fast visuomotor feed-back. Together, these mechanisms contribute to the emergence of dynamic, task-specific muscle synergies that allow the motor cortex to transcend hard-wired constraints and optimize behavior according to abstract goals. Schieber will show how monkeys can learn to coordinate small ensembles of arbitrarily selected motor cortex neurons to control a one-dimensional brain computer interface. He will describe the advantages conferred by using more neurons in an ensemble even when there is no guarantee that the neurons have been coordinated before.

PANEL Session 2

Tuesday, April 24

10:45 – 13:00

Variability and learning: chicken or egg?

Philip Sabes[1], Robert van Beers[2], Michael Brainard[1], Maurice Smith[3]

[1]University of California - San Francisco, [2]VU University Amsterdam, [3]Harvard University

Movement variability and motor learning are ubiquitous features of sensorimotor control, and there have been many suggestions that variability and learning are related in a fundamental way. Current thinking on this issue includes potentially conflicting views on the role of movement variability in the context of learning. One view, originating from the reinforcement learning community, is that variability is requisite for learning, as it represents an exploration of the underlying parameter space needed to optimize performance. In contrast, many researchers conceptualize motor variability as unwanted "noise" and model learning as a process aimed at minimizing variability. Models such as error corrective learning also

predict that movement variability is a consequence of learning. Finally, variability can be seen as a reflection of statistical uncertainty (e.g. about the movement goal), and learning as a process of statistical optimization in the face of an uncertain environment. Each of these views has theoretical and experimental support, a state of affairs that has led to confusion on this issue within the field. This panel brings together researchers that have been working within these disparate frameworks, using a range of behavioral and physiological studies in human, non-human primate, and songbird. The goal of the panel is both to provide a clear distinction between these views and to look for common ground. After a general introduction to these issues, Maurice Smith and Michael Brainard will argue that motor variability drives motor learning. Maurice Smith will discuss his recent work linking motor variability to motor learning ability. He will show that the temporal structure of motor output variability before learning predicts subsequent learning rates - both across tasks and across individuals in a single task, and that changes in learning ability lead to specific changes in the temporal structure of motor variability. Michael Brainard will discuss his work showing that movement variability is required for reinforcement-based learning of bird song. He will also present recent data exploring how the avian basal ganglia circuit both generates motor variability and drives motor learning. Robert van Beers and Philip Sabes will argue that while one of the goals of motor learning is to minimize task-relevant variability, a substantial component of motor variability arises during the act of learning. In particular, motor adaptation driven by noisy sensory information is modeled as a stochastic process that adds random elements to movement planning which can accumulate across movements, creating a random walk in "state-space" (i.e., in mean behavior). Robert van Beers will discuss his work on optimal learning in this context. He will show that optimal learning effectively eliminates noise accumulation in task-relevant aspects of movements, yet the random walk accumulation of noise does occur for task-irrelevant aspects. Philip Sabes will show that neuronal populations in premotor cortex also exhibit this random walk behavior, and will discuss the link between premotor cortex and movement variability. He will also discuss how learning can modulate variability. Finally, we will have a panel discussion on whether these views reflect different aspects of the same processes, whether they reflect completely different processes, or whether one view is simply wrong.

PANEL Session 3

Tuesday, April 24

15:00 – 17:15

The comparative design of neural circuits for mammalian skilled forelimb movement

Eiman Azim[1], Thomas Jessell[1], Roger Lemon[2], Mark Churchland[1], Bror Alstermark[3]

[1]Columbia University, [2]University College London, [3]Umea University

Skilled forelimb reaching and object manipulation are amongst the most refined forms of motor behavior. These complex movements exist in various forms across mammalian and non-mammalian tetrapods, ranging from basic scooping and wiping motions of frogs, to complex prehension and individual digit grasping in primates. Much like locomotion, reaching behavior is largely conserved across mammals, exhibiting remarkably equivalent limb extension, flexion, and rotation movements; nonetheless, the dexterity of prehension in particular has undergone dramatic evolutionary enhancement. Similarly, although mammals share some basic features of descending and spinal neuron connectivity, there are notable species-specific evolutionary circuit adaptations. Phylogenetic comparison may help to reveal how shared principles of mammalian circuit design underlie similar movements, and how evolutionary divergence in neural connectivity has been used to elaborate forelimb dexterity while still achieving the same broad biomechanical ends. Cat and primate models are particularly amenable to behavioral analysis and continue to reveal how dissociable components of forelimb movement are controlled, at least partially, by distinct spinal and

supraspinal circuits. More recently, mice have provided a potentially complementary model in which to genetically access and manipulate individual circuits to further investigate modular neural correlates of skilled movement. Here, we discuss bringing together these approaches, focusing on strengths and limitations of each model system. As an introduction, Thomas Jessell and Roger Lemon will provide an overview of cross-species, circuit-based analysis of skilled motor control. This framework of phylogenetic comparison and developmental molecular insight will provide a context for three examples in which the strengths of specific model systems are used to elucidate different aspects of forelimb movement. First, recent work in primate neocortex suggests remarkable similarity in neural pattern generation between reaching and more primitive movement. Mark Churchland will argue that the 'preferred direction', a cherished descriptor of neural coding during reaches, is an inconsistent surface-level feature that is secondary to the deeper structure of pattern generation. Experimentally observed changes in preferred direction - which appear to be a flaw in the neural code - are in fact expected and predictable. Second, investigating the motor command as it descends into the spinal cord, Bror Alstermark will discuss how physiological, anatomical, and behavioral analyses in the cat and primate have revealed propriospinal networks that communicate to motoneurons and cerebellar circuits, potentially providing a corollary discharge at the level of the forelimb. Finally, Eiman Azim will describe how this cat and primate work has informed recent attempts to genetically dissect and acutely manipulate mouse spinal and supraspinal circuits, revealing forelimb movement behavioral perturbations. This genetically tractable system provides remarkably specific spatial and temporal access to circuits that have been maintained and others that have diverged across evolution. We propose that by using the strengths of each model system and testing the results from one in the experimental and conceptual frameworks of another, a cross-species approach should provide a more complete understanding of the neural basis of skilled movements.

PANEL Session 4

Wednesday, April 25
8:00 – 10:15

Controlling movement in the octopus - from biological to robotic arms

Tamar Flash[1], William Kier[2], Benny Hochner[3], Dimitris Tsakiris[4], Cecilia Laschi[5]

[1]Weizmann Institute of Science, [2]University of North Carolina at Chapel Hill, [3]Hebrew University, [4]Institute of Computer Science of the Foundation for Research and Technology, [5]Scuola Superiore Sant'Anna

This session describes research on different aspects of the control of movement in the octopus and work on the development of robotic systems inspired by the octopus. William Kier: A diverse array of animal structures: mammal and lizard tongues, cephalopod tentacles and arms and the elephant trunk lack the rigid skeletal elements of vertebrates and arthropods and the fluid-filled cavities of many soft-bodied invertebrates. These structures, termed 'muscular hydrostats', instead consist of a densely packed three-dimensional array of muscles in which the musculature both produces the force for movement and provides the skeletal support. Since the musculature resists volume change, any decrease in one dimension must result in an increase in another. The musculature of these structures is typically arranged such that all three dimensions can be actively controlled, thereby allowing a wide variety of movements and deformations. Benny Hochner: We will describe how the octopus copes with the complex problems of controlling highly redundant limbs using two examples of arm movements- arm extensions with which the octopus reaches for targets and fetching movements with which the octopus brings a grasped object to its mouth. Kinematic analysis and EMG recordings have helped elucidate the control mechanisms involved. We will also describe the non-somatotopic organization of the higher motor center in the octopus brain which may be correlated with the unique division of motor control between the central brain and the

elaborate peripheral nervous system of the arms. Tamar Flash: To investigate what strategies underlie the control of octopus arm movements, methods and models allowing to characterize the movement kinematics and to decompose the movements into elementary primitives were developed. Dynamic models aimed at inquiring what muscle activation patterns and mechanisms subserve reaching, fetching and elongation movements and for assessing the arm stiffness will be described. Dimitris Tsakiris: Computational models for aquatic robotic systems inspired by the octopus involving the elastodynamics of their compliant arms and their hydrodynamic interaction with the environment will be presented. The arm muscular hydrostats are modelled as three dimensional nonlinear nearly-incompressible hyper elastic bodies, and finite element numerical simulations of their elastodynamics were performed. The hydrodynamic forces and flow field structure, resulting from biologically-realistic morphologies of octopus arms, were computed using high-fidelity computational fluid dynamic methods. These models are exploited to study the generation of single and multi arm behaviours and assist in the design of robotic prototypes. Cecilia Laschi: The muscular hydrostat represents a challenging model for the development of soft continuum robot arms with variable stiffness. An artificial muscular hydrostat has been developed starting from a flexible and conical braid specifically manufactured for this aim. It guarantees the continuity of the structure and provides anchorages for the actuation system. It is actuated longitudinally by multiple cables pulled from the base and transversely by SMA springs that can contract locally. The overall structure is soft but can stiffen locally and can execute bending, shortening and elongation in water. Novel technological solutions were required for the mechanical structure and control of the robotic arm.

INDIVIDUAL PRESENTATIONS I
Session 5

Wednesday, April 25
10:45 – 12:45

Control of gaze shifts in monkeys with vestibular prostheses

James Phillips[1], Leo Ling[1], Trey Oxford[1], Amy Nowack[1], Chris Kaneko[1], Albert Fuchs[1], Steven Bierer[1], Kaibao Nie[1], Jay Rubinstein[1]

[1]University of Washington

Introduction: Numerous authors have explored the function of the vestibulo-ocular reflex (VOR) during head unrestrained gaze shifts. Various results have been obtained in response to perturbations of the head and eye during such gaze shifts. These results have been interpreted to suggest that the VOR contributes to active gaze shifts but may be modulated during the gaze shift based on the difference between expected and actual head movement. These issues are complicated by the presence of a number of non-vestibular signals that may contribute to the performance of a gaze shift, especially during mechanical perturbations. To explore this question in more detail, we tested monkeys during head unrestrained gaze shifts by activating a chronically implanted multidimensional vestibular prosthesis to provide electrically driven vestibular signals in different directions relative to the intended gaze shift.

Methods: 9 monkeys were implanted with a vestibular prosthesis capable of real time canal specific stimulation of the vestibular end organ based on head velocity and acceleration or on a preprogrammed electrical stimulus. 6 monkeys had normal VOR responses to natural rotational stimuli and intact hearing after implantation. These animals had stable eye movement responses to electrical stimulation, stable evoked vestibular potentials, and stable electrode impedances. 3 of these monkeys were selected for head unrestrained behavioral experiments. Eye and head movements were recorded using scleral and head-mounted magnetic induction search coils. Before, during, and after active gaze shifts to sequentially illuminated LED targets that were blanked during the movement, the prosthesis was activated to produce a vestibular signal indicating

Precision Instrumentation for the Sciences

increased or decreased head velocity in the direction of the intended target, or head velocity in some other direction. Stimulation was performed at current amplitudes from 75 to 150 μA to vary the size of the false head velocity signal. The stimuli were delivered for varying durations ≥50 ms.

Results: Electrical stimulation of the semicircular canals produced changes in head, eye and gaze velocity during horizontal gaze shifts, and changes in gaze amplitude consistent with an active contribution from the canals to the control of gaze shifts. It was possible to modulate the size of the perturbation with stimulation current. The changes in velocity were smaller during the saccadic portion of a head unrestrained gaze shift than before or after it, or during a head fixed saccade, independent of stimulus direction relative to the direction of the gaze shift. There appeared to be a progression of VOR gain at different time points during the gaze shift. The response latencies were consistent with the latency of the VOR.

Conclusion: Electrical stimulation with a vestibular prosthesis is interpreted as a natural head velocity signal during active gaze shifts. The behavioral response is consistent with recent models of the control of gaze shifts using VOR signals weighted by the context in which they are encountered.

Functional roles of commissural inhibition and excitation between the superior colliculi for control of saccades in relation to Listings law and the VOR

Mayu Takahashi[1], Yuriko Sugiuchi[1], Yoshikazu Shinoda[1]

[1]Tokyo Medical and Dental University

Introduction: The commissural connection between the superior colliculi (SCs) was considered to be mainly inhibitory and mediate the "Sprague effect". However, we recently showed that there was also a strong excitatory connection between the SCs. To understand the functional roles of commissural inhibition and excitation of the SC on tectoreticular neurons (TRNs), we recorded intracellular potentials from TRNs and analyzed effects of stimulation of rostrocaudal and mediolateral sites in the contralateral SC on TRNs projecting to the Forel's H area (FFH) and/or the contralateral inhibitory burst neuron area in the brainstem of anesthetized cats. Caudal TRNs received monosynaptic inhibition from the rostral sites in the contralateral SC, whereas rostral TRNs received monosynaptic commissural excitation from the rostral part in addition to the commissural inhibition. Furthermore, medial TRNs in the rostral SC received strong commissural excitation from the medial part of the opposite rostral SC, whereas lateral TRNs received strong excitation from its lateral part, and medial and lateral TRNs received strong inhibition from the lateral and medial part of the opposite rostral SC, respectively. To provide morphological evidence for these electrophysiological findings, we examined tectal distribution of commissural excitatory and inhibitory neurons in the cat SC by injecting tracers into various parts of the SC, and the FFH. Double-labelling with GABA and gold particle-conjugated WGA -HRP (GP) was used to identify commissural neurons (CNs) as GABAergic. Lateral SC injections labeled small GABA-positive commissural CNs in the opposite medial SC and medium-sized GABA-negative CNs in its lateral part, whereas medial SC injections labeled small GABA-positive CNs in the opposite lateral SC and non-GABAergic medium-sized CNs in its medial part. These morphological findings support our electrophysiological results that the inhibitory commissural connection exists between the medial (lateral) SC representing upward (downward) oblique saccades on one side and the lateral (medial) SC representing downward (upward) oblique saccades on the other side. This pattern of reciprocal inhibition between the SCs is very similar to that seen in the oblique eye movements evoked by head rotation in the plane of anterior semicircular canal on one side and the posterior semicircular canal on the other side. Although it had been believed that the saccade system uses horizontal and vertical Cartesian coordinates, this similarity of reciprocal inhibition patterns of the SC saccade system and the semicircular canal system implies that the SC output system may use the same coordinate system as the semicircular canal system. In addition, mirror-symmetric excitatory connections between medial-medial and lateral-lateral parts of the SCs play an important role in conjugate upward and downward vertical saccades, respectively, because coactivation of TRNs in bilateral symmetric sites of the

rostromedial (rostrolateral) SCs might occur through the tectal commissural excitatory connections, and the torsional components of individual eyes, which are induced in opposite directions by the two SCs, seem to cancel each other, leaving mainly vertical components of saccades. Therefore, these excitatory commissural connections between the two SCs are considered to contribute to Listing's law.

Fractal fluctuations in movement variability: Insights into motor learning

Aaron Wong[1], Mark Shelhamer[1]

[1]Johns Hopkins University School of Medicine

Evidence for fractal behavior in physiology has been found at every level ranging from ion channel kinetics to firing rates of neurons to gross behavioral responses, although the meaning of these fractal fluctuations is unknown. It is thought that fractals reflect a system sitting at the boundary between order and disorder, which imbues such processes with stability while enabling rapid responses to environmental changes. In motor learning, fractal fluctuations exist in time series of predictive-saccade amplitudes. During this simple task, subjects automatically generate anticipatory movements in expectation of the requested movement amplitude. This predictive behavior requires future predictions to be updated according to performance errors in the past, yielding carryover of information between trials. Amplitude fluctuations have previously been demonstrated to constitute a fractal process: in particular, they exhibit power-law decay of the power spectrum (linear decay with nonzero slope on a log-log plot). Such power-law decay implies that the variability of the time series scales with the duration over which it is measured (a fractal characteristic); in practice, this means that such systems have multiple time scales of learning. Here, we demonstrate for the first time that such fractal behavior does indeed relate to the ability of a system to respond rapidly to errors. For each subject, we measured the fractal structure of their behavior during a predictive-saccade task. We immediately thereafter assessed their rate of learning during a standard saccade double-step adaptation task. We find a very strong association between the extent of fluctuations observed during this stationary predictive-saccade task (as measured by the slope of the power spectrum), and the adaptation rate. This is not related to the overall variability (standard deviation) of predictive-saccade amplitudes; only the structure of that variability (fractal fluctuations) is relevant. Furthermore, if subjects adapt at a faster rate, they utilize more of this fractal learning process. Thus, fitting and removing the major trend in the adaptation process leaves behind residuals, and the extent to which those residuals resemble white noise is inversely related to the rate of adaptation, independent of the extent to which subjects adapt. That is, the degree of fractal behavior exhibited reflects the ability of the system to respond to unexpected errors. This suggests that motor learning is supported by a complex learning process that flexibly corrects performance errors, while utilizing enough prior performance information to maintain stable long-term behavior. In short, fractals may reflect the ability of the motor system to synthesize appropriate movement responses using an appropriate (possibly optimal) combination of prior and incoming information.

Internal models for predictive saccades in a natural interception task

Gabriel Diaz[1], Joseph Cooper[1], Mary Hayhoe[1]

[1]The University of Texas at Austin

In the natural world, the brain must handle inherent delays in visual processing. One compensatory strategy is to combine prior experience with current sensory data to predict the future state of the visual scene. Previous research has suggested that the frontal and supplementary eye fields encode predictive information about target motion, and that this information is used to guide both saccadic and pursuit eye-movements. However, the factors that contribute to prediction are poorly understood. Furthermore, because most experiments have constrained the head and restricted target motion to the fronto-parallel plane, it is unclear how the findings might

generalize to the more natural situation in which targets move along complex trajectories in three dimensions, and viewpoint is unconstrained. In this study, subjects intercepted virtual balls in a simulated environment seen through a head-mounted display. On each trial, a launched ball bounced on the floor before its arrival at the subject. Trajectories were generated by a physics simulator (ODE) and both bounce point and point of initiation varied randomly over a pre-defined range. The subject used a racquet to hit the virtual ball at a target on the far wall. Ball trajectories were chosen so that, at the time of impact with the ground, the vertical component of the ball's velocity was one of three possible values. In addition, the elasticity of the ball was changed halfway through the experiment. On 83% of the trials, subjects initiated a saccade prior to the bounce, to a location 8° to 13° above the bounce-point. This location predicted the ball's post-bounce trajectory with high accuracy, so that the ball passed within 3.5° of the gaze point (+/- 0.53° SEM between subjects). Furthermore, saccade height scaled linearly with predicted post-bounce ball velocity so that the ball passed through the predicted location 141 (+/- 8) ms after the bounce in all conditions. Saccades were initiated 25-100 msec before the bounce, and this also varied linearly with post-bounce velocity. Because the effects of elasticity are not visible on the basis of pre-bounce information alone, subjects must have combined learned effects of ball elasticity with visual information about pre-bounce ball trajectory to predict where the ball would be after the bounce, and when it would get there. The internal model necessary for the spatial and temporal precision of the prediction in this task is substantially more complex than that required for prediction of targets moving along a 2D plane observed from a fixed viewpoint. Rather, the results implicate a complex internal model of ball dynamics that is able to account for changes in ball elasticity, 3D velocity, angle of incidence, and gravity. Note that, because trajectories are randomized and viewpoint is unconstrained, the model must be viewpoint independent. In reaching, there is evidence for the optimal Bayesian integration of current visual information with stored visual priors, (eg Koerding & Wolpert, 2004; and others). The present results raise the issue of whether a similar optimal weighting occurs with predictive saccades. It is likely that a number of brain areas are involved in this prediction, including frontal and supplementary eye fields, in addition to areas involved in the computation of visual motion. Supported by NIH grant EY05729.

An optimal control model of the compensatory eye movement system

Mark Ginzburg[1], Tafadzwa Sibindi[2], Maarten Frens[2], Opher Donchin[1]

[1]Ben Gurion University, [2]Erasmus MC

The compensatory eye movement system (CEM) maintains a stable image on the retina by using visual and vestibular input to drive eye movements that cancel movements of the head and the surroundings. Frens and Donchin [Front Cell Neurosci, 2009] proposed that this system can be explained using a state-predicting feedback control (SPFC) framework, and they proposed a specific match between the control structure and the underlying neural elements. We tested the viability of this framework by building a computational model for horizontal CEMs and compared simulated response to experimental data We collected in mice. Model structure and parameters were taken from existing literature, including known non-linearities in the vestibular and oculomotor systems. The LQG solution was used to approximate the optimal controller. We tested the model in four conditions: vestibulo-ocular reflex (VOR) in darkness, optokinetic reflex (OKR), VOR in light (VVOR), and visually suppressed VOR (SVOR). We used sinusoidal stimuli containing a wide range of frequencies (0-1 - 3.2 Hz) and amplitudes (0.5-8.0 °). The model reproduces the main properties of the experimental data. The model also reproduces three key pieces of data that were in the model's design: (1) output of the forward model (identified with the cerebellum, Frens and Donchin, 2009) is correlated to movement with zero lag (Winkelman and Frens, 2007, SfN poster); (2) elimination of the efferent copy (identified with nucleus prepositus hypoglossi, NPH, Green et al, 2007) reduces the time constant of the drift towards center (Cannon and Robinson, 1987, a finding that has been used to

argue for an inverse model in the NPH); (3) elimination of the forward model (cerebellum) reduces the gain of the OKR but not the VOR (Van Alphen, Schepers et al 2002; Rambold, Churchland et al 2002). Our work also shows that the SPFC framework is compatible with VOR adaptation, using a standard version of cerebellar plasticty through error-driven modification of Purkinje cell responses. Thus, our model explains how cerrebellum lessions affect VOR adaptation, but not VOR itself Our results suggest that the SPFC model of the compensatory eye movement system is a plausible framework for understanding the CEM system.

Memory and prediction in cerebral cortex, basal ganglia and cerebellum

Robert Scheidt[1], Nicole Salowitz[1], Janice Zimbelman[1], Aaron Suminski[1], Kristine Mosier[2], James Houk[3], Lucia Simo[3]

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If memory is to improve fitness for survival, it must shape future actions to satisfy shifting environmental demands. We used functional MR imaging (FMRI), a robotic device and systems identification techniques to examine neural correlates of predictive compensation for spring-like loads during goal-directed wrist movements. Although load changed unpredictably from one trial to the next, people nevertheless used sensorimotor memories from recent movements to predict and compensate upcoming loads. Prediction enabled subjects to adapt performance so that the task was accomplished with minimum effort. Population analyses of functional images revealed a distributed, bilateral network of cortical and subcortical activity supporting predictive load compensation. Importantly, the results reflect active engagement of three adaptive mechanisms known to contribute to motor learning [1-2]. Cortical regions (including prefrontal, parietal and hippocampal cortices) exhibited trial-by-trial fluctuations in BOLD signal consistent with storage and recall of sensorimotor memories or "states" (working memory) [3-4] assumed to be formed using some form of Hebbian learning. Bilateral activations in associative regions of the striatum were correlated with error costs and load predictions consistent with reinforcement learning [5] and prospective scaling of previously learned motor programs [6]. Activity in cerebellar cortex was consistent with supervised learning and, possibly, direct adaptive control of limb movement [7]. Analysis of single subject images found that predictive activity was as likely to be observed in multiple neural systems as in just one. Thus, predictive compensation in the presence of environmental uncertainty is mediated by adaptive mechanisms spanning multiple, distributed, cortical and subcortical structures. This distributed processing reflects active engagement of all three adaptive mechanisms that contribute to motor learning [2]: unsupervised learning in cerebral cortex, reinforcement learning in the basal ganglia, and supervised learning in the cerebellum.

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PANEL Session 6

Wednesday, April 25
14:30 – 16:00

Non-linear musculoskeletal properties: Blessing or burden for motor control?

Paul Gribble[1], Dinant Kistemaker[1], Knoek van Soest[2], Maarten Bobbert[2]

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A key question in motor control is how the CNS generates muscle activation patterns that govern voluntary movement. To what extent do non-linear visco-elastic musculoskeletal properties affect the complexity of the problems to be solved by the CNS? One might expect complex musculoskeletal behavior to increase the complexity of the control problem. Postulated neural mechanisms (e.g. internal models) for predicting the behavior of the musculoskeletal plant may have to take into account these properties. On the other hand muscle stiffness and damping are known to enhance stability. The aim of the first presentation by Dinant Kistemaker will be to highlight that the interaction between visco-elastic muscle fibers and elastic tendon plays a crucial role in the behavior of a muscle-tendon complex (MTC). This interaction decouples muscular and skeletal dynamics, allowing, for example, storage and release of energy, fast lengthening of muscles that occurs at impact, and energy production at high angular velocities like in throwing a fast ball. As a consequence of this decoupling, low-level effective feedback on the basis of muscle spindles alone is implausible.

However, it will be shown that a combination of spindle and Golgi tendon organ afferent signals can be used effectively in the control of posture and movement. Knoek van Soest will show that the dynamics of the open-loop controlled musculoskeletal system are importantly affected by the visco-elastic MTC. Examples will not only include phenomena such as the dynamics of force build-up and relaxation and the regulation of stiffness, but will also concern the ability to cope with small perturbations occurring during fast movements such as vertical jumping and smashing a table tennis ball; tasks that are likely to depend largely on open-loop control. Maarten Bobbert will highlight that visco-elastic MTCs simplify control, and that models used to explore control strategies should therefore incorporate these properties. For this aim, a musculoskeletal model of jumping controlled by a simple network of nine Hodgkin-Huxley type neurons and only ten synaptic weights will be used. Using jump height as criterion, the synaptic weights are optimized to map changes in initial posture to adaptations in control signals. After optimization, the network can automatically and immediately generate posture-specific control for successful jumps. This indicates that the CNS might in principle generate control signals for fast movements without using internal models of musculoskeletal dynamics. These presentations show that the complex properties of the musculoskeletal system of humans may in fact simplify the control of posture and movement.

INDIVIDUAL PRESENTATIONS II
Session 7

Wednesday, April 25

16:00 – 17:20

Monkey premotor and motor cortex reflect the decision process and determine the commitment to initiate a reaching movement

David Thura[1], Paul Cisek[1]

[1]University of Montreal

Motor control is traditionally seen as the output end of a series of perceptual, cognitive, and planning processes. However, recent neurophysiological studies have shown that brain areas implicated in the control of movement exhibit modulation related to a variety of decision variables. Do these variables simply "spill into" the sensorimotor system or is the sensorimotor system directly involved in making the choice? Is the commitment to a choice in fact determined within the sensorimotor system? We hypothesize that the process of commitment involves the combination, in the sensorimotor system, of the evidence favoring a given choice with information related to the urgency to respond, and that the product of these two is compared to a threshold for motor initiation. This mechanism provides animals with a simple way to achieve a trade-off between speed and accuracy which maximizes their average reward rate. To test this hypothesis, we trained a monkey to perform a task during which sensory evidence for given choices is changing in time, and recorded neural activity in the reach region of primary motor (M1) and dorsal premotor cortex (PMd). In our "tokens" task, the monkey begins each trial by placing a cursor in a central circle in which 15 small tokens are randomly arranged. The tokens then begin to jump, one-by-one every 200ms, from the center to one of two peripheral targets. The animal's task is to move the cursor to the target which he believes will ultimately receive the majority of tokens. The monkey is allowed to report his decision as soon as he feels sufficiently confident, and when he does so, the remaining tokens move more quickly to their final targets (either every 50ms or 150ms in separate "fast" and "slow" blocks of trials). The task allows us to calculate the temporal profile of the success probability of choosing each target, and to use it to characterize individual trials as easy, ambiguous, misleading, etc. The specific pattern of token jumps strongly affected the monkey's behavior. For instance, he decided more quickly and at higher success probabilities in easy trials compared to ambiguous trials. He also behaved more conservatively in the slow blocks than in the fast blocks. Multi-electrode recordings in PMd and M1 revealed that among a population of 123 cells (90 in PMd and 33 in M1) showing a rise of activity during the decision process, 62 (41 in PMd and 21 in M1) predicted the monkey's choices and reached a sharp peak of activity around the moment of commitment (which was estimated from behaviour). Prior to the moment of commitment, most of these decision-related activities reflected the profile of evidence presented to the monkey, with target selectivity emerging earlier in easy than ambiguous trials, activity switches reflecting changes-of-mind in misleading trials, and a level of activation at a given time significantly and positively correlated with the success probability calculated at that time. Finally, the amplitude of neural firing and the rate of build-up of many PMd and M1 decision-related neurons was higher in the fast than the slow blocks, reflecting the modification of the monkey's speed/accuracy trade-off. Our results suggest that neural activity in primary motor and dorsal premotor cortex continuously combines current sensory information with a growing urgency signal, and the commitment to a decision is made when this quantity reaches a motor initiation threshold.

Dorsal parietal area 5 encodes reaching component in sequential arm movement

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To generate a motor sequence, it is essential to integrate information regarding all temporally coordinated action components. Sequence-related activity has been observed in numerous cortical areas. In the posterior parietal cortex, the parietal reach region (PRR) has been found to encode both immediate and subsequent reaching goals (Baldauf et al., J Neurosci 2008). However, an action sequence ultimately must be decomposed into a series of discrete motor commands to be executed by the musculoskeletal system. It has been recently found that PRR encodes potential reach plans before effector decision (saccade vs reach) is formed (Cui and Andersen, Neuron 2007) while adjacent dorsal area 5 (area 5d) reflects only the decision outcome after the effector is unambiguously specified as the arm (Cui and Andersen, J Neurosci 2011), suggesting that area 5d is downstream to PRR in sensorimotor transformation. In the present study, we recorded single-neuron activity from area 5d while monkeys performed the double reach. Briefly, the monkey was required to touch a fixation center at the trial beginning. Then, the 1st and 2nd reaching goals were simultaneously displayed for 400ms with a

square and a triangle shifted counter-clockwise from the square by 135°, respectively. After a 600ms delay, the center dot turned off (GO) and the monkey was asked to touch the previously cued locations in the correct order. Single reach trials were randomly interleaved with the double reach trials for control. Among 76 task-related cells recorded so far, 26 (30%), 64 (84%), and 64 (84%) exhibited significant directional tuning during the delay (400ms before GO), pre-movement (200ms before the onset of the 1st reach), and peri-movement (200ms after the onset of the 1st reach) periods, respectively. In all 3 periods, the tuning curves were similar in the single and double reach trials. The tuning to the 2nd goal did not emerge until the 1st reach was done. To quantify tuning dynamics, we calculated the vector sum of the firing rate in a 200ms sliding window across all directions as the instantaneous preferred direction. Prior to the offset of the 1st reach, there was no significant difference in the preferred directions between single and double reach. Thereafter, the preferred direction in double-reach trials gradually rotated counter-clockwise toward the 2nd reaching goal. Around 100ms before the onset of the 2nd reach, the population-averaged shift saturated at 135°, co-varying with the switch of immediate reaching goal. We also calculated the Fano Factor (FF, as the variance vs mean of the spike counts) with a 100ms sliding window. In contrast to numerous other cortical areas shown by Churchland et al. (Nat Neurosci 2010), area 5d activity exhibited constantly low variability (FF = ~1.0) during the whole delay period. Although the FF increased sharply after GO (up to ~1.3), this tendency could be weaken by aligning the data to the movement onset (reduce to ~1.1) or by dividing fast and slow reaction trials (reduce to ~1.1-1.2 only), indicating that area 5d is less involved in sensory and cognitive processing but more tightly linked to motor control. Apparently, our results show that area 5d conveys no sequence-related information beyond the immediate reach, suggesting its possible role in translating cognitive sequences into detailed motor commands. This work is supported by Whitehall Foundation and Alfred P. Sloan Research Fellowship.

Evidence for plateau potentials in human subthalamic nucleus neurons in Parkinson's Disease

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The mammalian basal ganglia play critical roles in normal and pathological conditions. The connectivity between neurons of basal ganglia nuclei has been studied over several decades; this understanding has led to a number of models to explain, in particular, the pathophysiology of human diseases such as Parkinson's disease (PD). In addition, the electrophysiological properties of basal ganglia neurons have been studied in various model systems. Despite this understanding of connectivity and basic properties of basal ganglia neurons, the operation of these circuits in health and disease is still not well understood.

This knowledge deficit could in part be explained by the difficulty in understanding the operations of microcircuits involved in the control of movement. This is well illustrated by studies of the stomatogastric ganglion, which contains fewer than 30 neurons in total. STG neuronal physiology and connectivity are very well characterized. Investigations of STG have revealed that networks and neuronal properties can be "reconfigured" for different motor behaviours. It is clear from even this simple network that the thorough characterization of complex neuronal properties is critical towards understanding the modus operandi of neural circuits.

In order to understand microcircuit dysfunction in human PD, we first asked whether basal ganglia neuronal properties in PD could be studied in humans. We selected subthalamic nucleus (STN) neurons, as this is a common target in deep brain stimulation surgery for PD. Furthermore, it had been shown that these excitatory neurons have interesting electrophysiological properties when studied in slice preparations of the rat brain. In particular, it had been shown that they have "silent plateau potentials" (firing is interrupted during the plateau potential; Kass and Mintz, 2006, PNAS 103:183-8). We hypothesised that we could find fingerprints of such plateau potentials in human STN in PD.

To study plateau-like properties in human STN, we used single extracellular microelectrodes with exposed tips of ~40 μm and impedances of 500-1,000 kΩ. Between 2001 and 2011, STN neurons were recorded in 25 patients (50 STNs) (between 42-73 years, mean: 60, median: 59). All recordings were performed by a single surgeon (RB). Neurons were stimulated through the recording electrode with parameters of 200-300 Hz for < 500 ms, 0.2-0.5 ms pulses, and < 10 μA. Similar to what has been seen in the rat, this stimulation could repeatedly elicit a short burst of action potentials followed by a silent period that could last many seconds. A subsequent single shock could lead to termination of the silent period and resumption of typical STN firing. These findings parallel those in the isolated rat STN, in which the silent period is associated with a stable, depolarised state, or plateau potential (Kass and Mintz, 2006).

These data provide evidence for silent plateau potentials in human STN neurons in PD. We suggest that exploration of these properties could lead to further understanding of the circuits involved, and hence to more refined treatment strategies aimed at "restoring" circuit properties altered in disease.

Impaired retention of visuomotor adaptation in Parkinson's disease, improved with cortical stimulation

Raed Joundi[1], John-Stuart Brittain[1], Marko Bogdanovic[1], Tipu Aziz[1], Peter Brown[1], Ned Jenkinson[1]

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Motor adaptation is a process whereby performance is improved through reduction of errors, resulting in a motor memory which can persist over time. Evidence suggests that patients with Parkinson's disease (PD) have intact learning but impaired retention of a learned adaptation. The latter could be secondary to disrupted sleep in PD or a primary manifestation of basal ganglia dysfunction. Here, we hypothesized that retention of a visuomotor adaptation would be impaired even at short time scales. Moreover, by raising cortical excitability through transcranial direction current stimulation (TDCS) we sought to partially alleviate this deficit. We tested medicated patients and healthy controls on a visuomotor rotation task in which they had to move a cursor on a computer screen with a joystick towards a target that jumped to one of eight radial positions. During the baseline phase, the cursor moved as expected. During adaptation phases, the cursor was rotated so as to perturb the intended movement, and subjects had to gradually adapt over the testing session. In experiment 1, subjects performed the task without any stimulation. Subjects were first tested on a baseline phase (no rotation). A learning phase (60 degree rotation) was then imposed, designed to test initial error reduction. Next, a retrieval phase (60 degree rotation) was performed 45 minutes later to test the degree of retention. Lastly, a de-adaptation phase (no rotation) was performed immediately after the retrieval phase to study the ability of subjects to 'un-learn' the acquired motor memory. In experiment 2, a separate cohort of PD patients performed the task with either TDCS (2000 microamps) or sham stimulation over the motor cortex throughout the baseline and learning session, and 15 minutes afterwards. Patients then returned 40 minutes later for retrieval and de-adaptation phases. Our results in experiment 1 showed no significant difference between PD patients and controls in the learning phase, thus demonstrating intact learning of the visuomotor adaptation. However there was a large deficit in retaining the adaptation when tested 45 minutes later. There was also a slowed de-adaptation in PD. In experiment 2, TDCS improved both retention and de-adaptation compared to sham stimulation. The preserved learning in PD may be due to the involvement of the cerebellum in this process, a structure that is relatively intact in PD. In contrast, our results strongly implicate the cortico-basal ganglia system in the longer-term retention of acquired motor memories. This deficit in PD could potentially disrupt processes important for rehabilitation and motor improvement. As such, our results from experiment 2 raise the possibility of using TDCS to improve the effectiveness of rehabilitation in PD.

PANEL Session 8

Thursday, April 26
8:00 – 10:15

Neural mechanisms at the basis of action observation, motor simulation and action prediction: What have we learned in the past years?

Thierry Pozzo[1], Claudia Domingues Vargas[2], Valeria della Maggiore[3], Luciano Fadiga[4], Charalambos Papaxanthis[5]

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Convergent studies indicate that the human motor system can be activated by the observation of actions of other individuals. Similar effects of motor facilitation have also been found during motor imagery, i.e. the kinesthetic imagination to perform an action. Given that these phenomena have been proved to facilitate motor learning, they are currently of great potential in the implementation of therapies oriented at the recovery of sensorimotor function following cerebral injury. Neuroimaging data suggests that action observation and action simulation, although, respectively, passively and actively evoked, share similar neural substrates. In this symposium we intend to explore further the neural mechanisms at the basis of these phenomena based on novel findings from a team of specialists in the neuroscience of human motor control coming from Latin America, France and Italy. We will discuss data gathered from approaches that are in favour and against this view and how these findings fit within the frameworks of motor prediction and the mirror neuron (MN) system and how a MN based mechanism may subserve communication and language. T Pozzo, will introduce these topics and the 4 speakers: C Papaxanthis will present behavioural and TMS results concerning motor imagery and action observation. Functional similitudes between these two elusive mental phenomena will be discussed, in particular their association to forward internal models and to the actual state of the body. C Vargas will present behavioural and electroencephalographic findings on the ability to anticipate actions performed by others. She will explore how inference mechanisms allowing the detection of transiently hidden actions and the discontinuity of visual input could constrain the observer to recall implicit action representations, thus forecasting their unfolding. The neural underpinning of predicting upcoming actions will also be explored by showing that lesions in the parietal but not the premotor cortex affects this capacity. V Della-Maggiore will present convergent findings from CSE and fMRI supporting the hypothesis that action observation originates from sensorimotor learning. She will propose an alternative view to the existence of a specialized mirror system relying on the neural machinery supporting motor control, learning and memory. Thus, motor resonance induced by action observation could simply be explained by the retrieval of the motor program associated with the observed action and its covert activation. In addition, she will discuss her recent findings supporting that motor resonance induced by action observation may indeed act as a neural interface for action understanding. L Fadiga will present evidence from fMRI, TMS and human patient data in favour of a functional role played by action representation in forming the basis for a supramodal syntax. Thus, language may have evolved from more basic sensorimotor circuits already present in lower primates. During implicit/explicit interaction between individuals the motor involvement is bidirectional and communicative in nature, because of the mirror properties of the motor system. In disagreement with some interpretations, he will present evidence that the sensorimotor representation of others' actions does not require mentalistic or cognitive mediation being the result of a hardware link between premotor and parietal areas.

INDIVIDUAL PRESENTATIONS III
Session 9

Thursday, April 26

10:45 – 12:05

Predicting and correcting human ataxia using a model of cerebellar function

Nasir Bhanpuri[1], Allison Okamura[2], Amy Bastian[3]

[1]Johns Hopkins University, [2]Stanford University, [3]Kennedy Krieger Institute, Johns Hopkins School of Medicine

The movements of patients with damage to the cerebellum are ataxic, i.e. uncoordinated and dysmetric (patients over- or undershoot targets). It has been hypothesized that the cerebellum houses an internal dynamic model that normally relates motor commands to changes in body state (e.g. arm position and velocity). We proposed that when the cerebellum is damaged, the resulting ataxia is caused by a mismatch between the brain's modeled dynamics and the actual body dynamics. We studied people with and without cerebellar damage as they performed single-jointed reaches in an exoskeleton robot that could render specific dynamic changes to the arm (e.g. increasing or decreasing inertia). We use behavioral and computational approaches to demonstrate that specific cerebellar deficits result from a mismatch in internal versus actual arm dynamics. Our patient model, which includes a feedforward internal model, body dynamics, and sensory feedback, can predict individual patients' dysmetria due to specific biases of internal model inertia estimates. In addition, we are able to reproduce patient-like deficits in behavior of controls by unexpectedly modifying arm inertia--thereby imposing a mismatch between the actual and internal estimates of the arm. Furthermore, the same computational framework can be used to simulate control behavior for a variety of unexpected perturbations (i.e. increased/decreased inertia/viscosity). Last and most importantly, the application of patient-specific compensations results in an improvement of their reaching. Specifically, inertia reduction for overshooters (n=5) caused a significant decrease in overshoot (p<0.005), while inertia increase for undershooters (n=4) caused a significant decrease in undershoot (p<0.05). These results support the idea that an intact cerebellum is critical for the upkeep of accurate internal models of dynamics. Importantly, we show that correcting the mismatch through patient-specific compensations improves movement in cerebellar patients, who are notoriously unresponsive to rehabilitation.

A stimulation approach to analyze the neural error signals controlling cerebellum-dependent motor learning

Jennifer Raymond[1], Barbara Nguyen-Vu[1], Jacob Rinaldi[1], Rhea Kimpo[1], Christina Kim[1]

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We analyzed the neural events controlling the induction of motor learning. Recording experiments have suggested that the cerebellar climbing fibers and Purkinje cell simple spike activity each carry potentially useful instructive signals during the induction of learning. We assessed the extent to which direct, optogenetic activation of the climbing fibers or the Purkinje cells could replace the sensory error signals that normally drive motor learning. For these experiments, we used the vestibular ocular reflex (VOR) learning paradigm, and viral vectors to selectively express channelrhodopsin in the climbing fibers or Purkinje cells.

Learned changes in VOR gain can be induced by pairing a vestibular stimulus with a moving visual stimulus. The visual stimulus and the associated visually-driven eye movements elicit responses in the both the climbing fibers and the Purkinje cells, and the timing of those neural responses relative to the vestibular stimulus encodes the required direction of the learned change in VOR gain (increase vs. decrease).

If we replaced the visual stimulus with direct, optogenetic activation of

the climbing fibers at the time during the vestibular stimulus when they normally fire during gain increase training, the gain of the VOR increased relative to the control condition with no climbing fiber stimulation. However, if we stimulated the climbing fibers at the time that they normally fire during gain decrease training, there was no change in VOR gain relative to control. These results suggest that the error signals carried by the climbing fibers are not always translated into long-lasting changes in the motor circuitry, and that climbing fiber-triggered plasticity mechanisms contribute selectively to certain aspects of motor learning, and not others.

We also assessed the extent to which direct, optogenetic activation of the Purkinje cells could replace the visual signals that normally drive VOR learning. Activation of the Purkinje cells at the time during the vestibular stimulus when they normally fire during gain increase training caused an increase in VOR gain relative to control, providing causal evidence for the longstanding hypothesis that Purkinje cell simple spike activity can control the induction of plasticity. However, if we activated the Purkinje cells at the time when they normally fire during gain decrease training, there was no change in VOR gain relative to control, suggesting that Purkinje cell activation, like climbing fiber activation, contributes selectively to VOR gain increase learning.

Mapping lesions to abnormal arm kinematics during recovery from cerebellar stroke

Juergen Konczak[1], Dagmar Timmann[2]

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Loss of movement coordination is the main symptom after cerebellar infarction. Detailed kinematic descriptions of acute stage ataxia are rare and no attempt has been made to link improvements in motor function to measures of neural recovery and lesion location. This study provides a comprehensive assessment of how lesion site and arm dysfunction are associated in the acute stage and outlines the course of upper limb motor recovery for the first four months after the infarction.

Methods: 16 adult patients with cerebellar stroke and 11 age-matched healthy controls participated. Kinematics of goal-directed and unconstrained finger pointing movements were measured at the acute stage and in a 2-week and 3-month follow-up. Magnetic resonance imaging (MRI) data were obtained for the acute and 3-month follow-up session. A voxel-based lesion map subtraction analysis was performed to examine the effect of ischemic lesion sites on kinematic performance.

Results: In the acute stage nearly 70% of patients exhibited hand velocity and acceleration maxima below the range of the control group leading to prolonged movement times. MRI subtraction analysis revealed that in patients with impaired motor performance lesions were more common in paravermal lobules IV/V and affected the deep cerebellar nuclei. By the 2-week-follow-up hand kinematics had improved dramatically (peak acceleration gains up to 86%). Improvements between the 2-week and the 3-month-follow-up were less pronounced.

Conclusion: In the acute stage arm movements were mainly characterized by abnormal slowness (bradykinesia) and not dyscoordination (ataxia). The motor signs were associated with lesions in paravermal regions of lobules IV/V and the deep cerebellar nuclei. Motor recovery was fast with the majority of gains in upper limb function occurring in the first two weeks after the acute phase.

Computational control of the conditioned eye blink reflex in rodents

Robert Prueckl[1], Aryeh Taub[2], Roni Hogri[2], Ari Magal[2], Matti Mintz[2], Christoph Guger[1]

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Brainstem facial nucleus (FN) contains motor neurons which upon activation by either neuronal afferents or electrical trains induce eye blink responses. The goal of the present study, which was conducted in the course of the European Union project ReNaChip, was to replace the cerebellar micro-circuit, which is responsible for acquisition of the conditioned eye blink response, with a biocompatible synthetic prosthesis. In this project, for the first time a functional real-time system was developed which utilized biological streams directly from and to the brain.

The conditioned eye blink response is learned along a classical conditioning paradigm. Typically, it consists of a several hundreds of milliseconds long tone, which is used as a conditioned stimulus (CS), co-terminating with a short air puff directed to the eye of the subject. The air puff serves as unconditioned stimulus (US) and elicits an unconditioned response (UR) in form of a fast eye blink after its onset. After a sufficiently large number of paired CS-US trials the cerebellar microcircuit adapts in a way that it initiates conditioned eye blink responses (CR) in reaction to the CS's, and therefore before the arrival of the air puff. The functionality of the cerebellar micro-circuit is lost with age and senescent rats fail to acquire the conditioned eye blink response. This age-related deficiency and the elaborate knowledge about the cerebellar microcircuit made the cerebellum an eligible candidate for testing the feasibility of rehabilitation based on replacement technology.

The neuronal representations of the CS and the US arrive in the course of the classical conditioning procedure in the brainstem pontine nucleus (PN) and the inferior olive (IO), respectively, and from there are routed to the cerebellum. The two pathways converge in the cerebellar cortex where the association between the stimuli is established and consequently the cerebellar output conveys a model-CR to the FN which initiates the peripheral eye blink-CR.

Using the real-time system which was developed for this study, paired CS-US trials were applied and multiple unit activity from the mentioned brain regions PN and IO of an anaesthetized rat were recorded utilizing arrays of microelectrodes, headstages and biosignal amplifiers. After the training of signal processing algorithms which were to detect the time of the CS and US onset out of the biosignals, the real-time experiment started. The stimuli were detected in real-time and conveyed to an algorithm which modeled the functionality of the cerebellum and - also in real-time - established the association between the stimuli. It finally reacted with a trigger which symbolized the CR. This was sent to an electrical stimulator connected to an electrode implanted in the FN of the animal. The pulse train, which had the same duration as a typical CR, caused the eye blink response.

In this study the successful implementation of a prototype neural prosthesis is presented, which interacts directly with the brain in a closed loop manner and triggered well timed learned motor responses. The system is a proof-of-concept for the feasibility of highly specialized and spatiotemporally accurate neural prostheses.

PANEL Session 10

Friday, April 27
8:00 – 10:15

The contribution of sensory signals in constructing brain-machine interfaces

Aaron Suminski[1], Sliman Bensmaia[1], Joseph O'Doherty[2], Kevin Otto[3]

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The ultimate goal of brain-machine interface (BMI) research is to create a device that provides individuals suffering from severe motor disabilities a complete restoration of function. Historically, much of the effort in BMI research has focused on the efferent component of the device, that is, the decoding of neuronal signals to control mouse cursors or robots. Comparatively little effort has been devoted to the afferent (or sensory) component of the BMI despite a wide acknowledgement of its importance. In this session, we will describe two ways in which sensory signals will contribute to BMIs. First, we will describe how precise and behaviorally-relevant sensory percepts can be conveyed to the patient via intracortical microstimulation (ICMS). Indeed, we will explore how ICMS can elicit percepts with a specific sensory magnitude, percepts with specific temporal properties, and percepts projected to specific locations on the prosthesis. Second, we will discuss how artificial sensory feedback

may actually have a beneficial effect on signals used for control in the efferent component of the BMI. Kevin Otto will describe sensory prostheses using intracortical electrical microstimulation based on consistent and efficient activation of neurons in the targeted cortical region. He will discuss the optimization of pulse rate and stimulus waveform to produce longitudinal, behaviorally detectable stimuli in a rat animal model. Joseph O'Doherty will discuss temporal patterns of ICMS as a means of encoding somatosensory percepts. He will demonstrate that temporally patterned ICMS pulse trains enable artificial active exploration; that periodic and aperiodic pulse trains are discriminable, suggesting potential for percept encoding beyond simple frequency codes. Furthermore, he will show that complex temporal patterns of ICMS can be used to convey information about the spatial frequencies of artificial textures. Sliman Bensmaia will describe recent results showing that spatially localized percepts can be elicited by electrically stimulating a spatially restricted population of neurons in primary somatosensory cortex. This spatial information can used to intuitively convey to the prosthetics user where the prosthesis is contacting a grasped object. The ability to convey feedback that varies along multiple sensory dimensions - intensive, temporal and spatial - will play a major role in guiding state of the art prosthetic limbs, which can comprise up to twenty or more degrees of freedom. Aaron Suminski will demonstrate that a BMI combining naturalistic proprioceptive and tactile feedback with vision outperforms a BMI utilizing visual feedback alone. Using the information about movement direction represented in the spiking activity of MI neurons, he will show that somatosensory feedback not only contributes to the guidance of movement but also impacts the quality with which intended movements are decoded. We will reserve ample time for a discussion of both coding information in sensory cortices using ICMS and the impact artificial sensory feedback on the control of brain-machine interfaces.

INDIVIDUAL PRESENTATIONS IV
Session 11
Friday, April 27
10:45 – 12:45

Information processing in human tactile afferent neurons

J. Andrew Pruszynski[1], Roland Johansson[1]

[1]Umea University

The cutaneous receptive fields of human fast-adapting and slow-adapting type I afferents (FA-I and SA-I) contain multiple zones of high sensitivity. The presence of these 'hotspots' likely reflects the spatial locations of the multiple end-organs innervated by a single afferent fiber as it branches in the skin. Very little is known about the functional role of this spatial arrangement. We hypothesize that the spatial arrangement of hotspots allows a single primary afferent to signal particular spatial features of a tactile stimulus. That is, we predict that the responsiveness of an afferent neuron is determined by the degree to which local skin deformations coincide with the locations of its hotspots. To test this hypothesis, we used microneurography to record from FA-I and SA-I afferent neurons while tactile fine forms were scanned across the fingertip at a constant speed (30 mm/s) and contact force (~0.4 N). We used a range of items including dots, lines, squares and diamonds of different orientations, all of which were embossed (0.5 mm height) on an otherwise flat surface. Consistent with previous reports, we found that receptive fields of both FA-I and SA-I afferents possessed multiple hotspots, that the distribution of the hotspots showed a range of configurations and orientations, and that both types of afferents broadly represented the major geometrical properties of the tactile items. Our results revealed that the orientation of the scanned items could dramatically affect afferent responses and that afferents could be sensitive to a range of complex features such as sharpness of corners, leading/trailing edges and the direction of motion across the receptive field. Critically, the spatial organization of hotspots for a particular afferent frequently predicted its sensitivity in

these respects. We submit that the terminal organization of tactile afferents constitutes a mechanism for processing information about the spatial features of a contacted object before the signals ever enter the central nervous system.

Genetic dissection of the spinal circuit for hand dexterity in macaque monkeys

Tadashi Isa[1], Masaharu Kinoshita[1], Ryosuke Matsui[2], Shigeki Kato[3], Taku Hasegawa[2], Hironori Kasahara[2], Kaoru Isa[1], Akiya Watakabe[4], Tetsuo Yamamori[4], Yukio Nishimura[1], Bror Alstermark[5], Dai Watanabe[2], Kazuto Kobayashi[3]

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In primates, the corticospinal tract originating from the motor cortex is connected with hand/arm motoneurons not only with the direct connection but also with indirect pathways mediated via spinal interneurons. Generally, the primate-specific ability of precision grip with independent control of individual digits has been ascribed to the function of the direct cortico-motoneuronal pathway, and the function of the latter, non-monosynaptic pathways, which is "phylogenetically older", has been elusive. Here, the function of the indirect pathway was assessed by newly developed genetic tool for reversible blocking of synaptic transmission of a specific neural pathway in macaque monkeys. By combining injections of lenti-viral vector psuedotyped with fusion glycoprotein (FuG-B) for highly efficient retrograde transport carrying a novel enhanced tetanustoxin (eTeNT) and enhanced green fluorescent protein (EGFP) in the downstream of TRE-sequence into the ventral horn of the C6-Th1 segments, and subsequent injection of adeno-associated virus-type 2 (AAV2) vector carrying a novel highly efficient Tet-ON promotor sequence rtTAV16 into the intermediate zone of the C3-C5 segments of macaque monkeys, we could reversibly control the expression of eTeNT and EGFP in the propriospinal neurons (PNs) in the C3-C5 segments projecting to the hand/arm motor nuclei in the C6-Th1 segments with application of doxycycline (Dox). Two-five days after start of oral application of Dox, the monkeys showed clear deficit in reach and grasp movements with their forearm. In these monkeys, electrophysiological experiments demonstrated block of the synaptic transmission from the PNs to hand/arm motoneurons during the period of Dox application. Histological examination revealed that a group of spinal interneurons in the lateral portion of the intermediate zone of the C3-C5 segments were labeled with anti-GFP immunohistochemistry. Not only the cell bodies and dendrites, but also their axonal trajectories could be traced to their descending terminals in the motor nuclei of the C6-Th1 segments and ascending terminals in the lateral reticular nucleus of the brainstem. These results showed that the non-monosynaptic cortico-motoneuronal pathways mediated via PNs are critically involved in the control of dexterous hand movements in monkeys.

Muscle activity during voluntary movement is generated and controlled by spinal interneurons that mediate proprioceptive reflex in awake, behaving monkey

Kazuhiko Seki[1], GeeHee Kim[1], Tomohiko Takei[1]

[1]National Institute of Neuroscience

Organization of spinal reflex pathway in vertebrate is well established in the anaesthetized or decerebrated animals, but there are no direct evidence showing their function in the generation and control of muscle activity during voluntary movement. To address this issue, we identified spinal interneurons (INs) mediating segmental reflex from proprioceptors and examined their activities during normal voluntary movement. Three macaque monkeys were trained to perform wrist flexion and extension task with an instructed delay period. An oval spinal chamber was implanted to vertebrae (C4-T1) and a glass-coated elgiloy microelectrode was used to record the activity of INs. Electromyographic activities (EMGs) were recorded from wrist flexor

and extensor muscles (n=8-12) by chronically implanted wire electrodes. In addition, nerve cuff electrode was implanted to the deep radial (DR) nerve that innervates most of wrist extensor muscles. In the monkeys performing wrist movement, we identified the peripheral input to INs by their responses to the electrical shock to the DR afferent. The INs that responded within a segmental latency of 1ms were identified as the cells with direct projection (1st-order INs) from DR afferents. Output of these INs to muscles were examined by the spike-triggered averaging of EMGs. In the 81 INs that showed response to the DR stimuli whithin a monosynaptic latency, 32 INs (39%) showed postspike effects to one or more muscles (22 post-spike facilitations (PspF, 69%), 7 post-spike suppressions (PspS, 22%), or 3 PspF & PspS (9%)). Among 22 INs with PspF, 18 INs (82%) showed their PspF exclusively in the extensor muscles, and number of muscle that showed PspF from each INs ("muscle field") was 2.0±1.03. These results suggest that the postsynaptic INs that mediating proprioceptive input from extensor muscles is excitatory, and extensor muscles were preferentially recruited by these INs (autogenic facilitation). Next, we analyzed the modulation of firing rate of first-order INs as a function of task sequence. First-order INs with PspF to extensor muscles (n=18) showed sustained activity throughout the extension torque. In contrast, the first-order INs without PspF (n=49) facilitated transiently during torque onset, but it decreased significantly while monkey sustained extension torque (p< 0.01). These results indicate that disynaptic, excitatory reflex pathway that mediating autogenic facilitation of extensor muscle is involved in the maintenance of static muscle force during voluntary movement. We propose that voluntary muscle activity could be automatically augmented using this reflex system.

Reticulospinal contributions to coordinated finger movement: Evidence from startle

Claire Honeycutt[1], Michael Kharouta[1], Eric Perreault[1]

[1]Northwestern University

A startling acoustic stimulus involuntarily releases planned ballistic movements, referred to as startReact. StartReact movements are readily elicited at the wrist and elbow. Recent evidence indicates that distal musculature of the hand, specifically the first dorsal interosseous (FDI) muscle, is not susceptible to startReact (Carlsen 09). As startReact is mediated through the reticulospinal tract, the lack of startReact in FDI was explained by relatively few reticulospinal projections to this muscle. There are reticulospinal projections to distal hand muscles, but it has been suggested that these projections mediate different tasks than the corticospinal tract (Baker 07). Specifically, severing of the corticospinal tract results in a loss of fine, individuated finger control but leaves coordinated finger movements, like grasp, intact. Therefore, we hypothesize that startReact will be present in FDI during those tasks shown to be mediated by the reticulospinal tract (e.g. grasp), but not in tasks requiring individuated finger movements. This would indicate that the ability to elicit startReact is pathway dependent and not related to a proximal-distal gradient. Data were collected in 6 subjects performing two finger tasks. The first was index finger abduction - identical to that performed in Carlsen 09. The second was a grasp task. Electromyography was recorded in the FDI muscle - activated during both tasks. Subjects performed each of these tasks following two non-startling acoustic stimuli of 80dB. The first sound represented "get ready," the second represented "go." Randomly, the second "go" was replaced with a startling acoustic stimulus of 128dB. Sternocleidomastoid (SCM) activation indicated a startle occurred. Trials were split into SCM (startle) and SCM- (no startle) and the latency of muscle activity in the FDI quantified. If our hypothesis is supported, we should find that the presence of startle (SCM vs -) should have a statistically significant effect that interacts with task. Further, presence of startle should have no effect during finger abduction (absence of startReact) but a significant effect during grasp (presence of startReact). We found results that supported our hypothesis. ANOVA testing confirmed that latency was significantly affected by the presence of startle (F = 30.31, p = 0.0001) and there was a significant interaction (F = 8.86, p = 0.0094) with task. Confirming Carlsen 09, startReact was not present during finger abduction: no statistical difference was found between SCM and -

trials (p = 0.09). Confirming our hypothesis, startReact was present during grasp task: there was a significant difference between SCM and - trials (p = 0). These results suggest that startReact can be elicited even in the distal musculature of the hand if the task is mediated through the reticulospinal tract. This indicates that the reticulospinal tract can exert influence on coordinated finger movements in humans, as it does in the monkey (Baker 07). This is significant for rehabilitation as the reticulospinal tract may provide an effective target for rehabilitating certain finger tasks following the loss of corticospinal tracts, such as during stroke.

Spinal selection of modular elements: Spinal motor planning evidence from combined neural and EMG analysis?

Corey Hart[1] Simon Giszter[1]

[1]Drexel University College of Medicine

Our work has focused on identifying the spinal structural modularity in motor control. Our recent data using ICA in intact frogs support the idea that the bulk of voluntary prey strike motor patterns in frogs may arise using spinal motor primitives found in spinalized frogs (i.e. unitary synergy bursts). We have now made recordings of large numbers of cells from the intermediate zone of the frog spinal cord and found evidence for populations of cells with motor pool projection patterns that match strongly with motor primitives identified via ICA. Apart from these neurons, there is considerable variability in the temporal relationships between the bulk of neural firing recorded and the ICA-extracted "modules" or primitives: some cells are active near the beginning of a primitive, some at its peak amplitude, and some near its completion. In many cases, neural activity related to primitive onsets precedes the actual primitive onset by 10s or even hundreds of milliseconds. Rather than simply representing hard-wired elements in a chain, the intermittency of these neurons' firing behavior implies a dependence on context, making the cells appear similar to so-called "decision cells" identified in a variety of behavioral contexts (Wong 2006) in other preparations. Simultaneous neural and EMG recordings were made in laminectomized and spinalized frogs. EMG recordings were made in 10 muscles of the right hindlimb using implantable electrodes. Simultaneous neural recordings were made in the deep intermediate zone of the cord with a custom-built tetrode electrode design. Neural activity was recorded using a 128 channel Cerebus systems (Black Rock Microsystems) and sorted using a t-distribution based spike sorting algorithm (Shoham 2003). After sorting, spike trains were examined for evidence of statistically significant increases in neural firing prior to onset of activity in particular ICA-identified primitives. Those neurons that demonstrated significant "ramping" of firing rate prior to primitive onset were retained and identified as potential switching or decision cells. These cells were further classified based on their firing patterns. There appeared to be two distinct classes of pre-onset behavior: (1) those cells in which the increase in firing rate was spread over many tens to hundreds of ms before primitive onset, which were classified as "ramp" cells, and (2) those with rate increases that occured about 10ms or so before the onset of a primitive, and were classified as "trigger" cells or "startup" cells. Because primitives often occur in Markov chain-like sequences in behaviors, we examined potential correlations to search for specific sequence switching, and "switch decision cells". We look for evidence that neurons correlate significantly with transitions between particular primitives. We then assessed the strength of relationships between particular decision cells and primitives using causality metrics such as Granger causality. A number of neurons satisfying these criteria have been found, suggesting there exist a collection of circuits that manage sequence switching, presumably connected with the primitives in pattern shaping levels, operating beneath rhythm generation systems within a hierarchy supporting spinal pattern generation and episodic reflex motions in the spinal cord. Supported by NIH NS40412, NS072651 and NSF IIS0827684

Optimal control of eye-head movements with changing head plant characteristics

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Large gaze shifts from one visual target to the next usually involve combined eye and head movements. While there are infinitely many possible solutions to the problem of choosing a movement, experiments show that the contributions of eye and head and the trajectories chosen are stereotyped. This suggests an underlying general principle governing the movement choice. We recently showed that basically all features of natural human eye-head movements - including the part where gaze is already on target and the eye counter-rotates - are reproduced by an optimal control model minimizing the impact of two types of noise, namely signal-independent or constant and signal-dependent noise, on the variability of the final gaze position after the gaze shift (Saglam et al. J Neurosci 31: 16185-93, 2011). Thus, the optimization criterion only takes into account the desired goal of stabilizing gaze on the newly selected target, but not other possible constraints that has previously been proposed, such as minimal effort. Due to including constant noise, the present model not only predicts features such as relative contributions of eye and head or the time course of the movement, but also movement duration.

In the present work, we ask whether and how changes in the dynamical characteristics of the effectors are taken into account for control of movement. Immediately after experimentally increasing the head inertia characteristic head oscillations around the end-point of the head can be observed, while gaze remains stable because the eyes counter-rotate. Here we show that, according to the model, head oscillations during the gaze stabilization phase increase movement cost by increasing variability during the gaze-stabilized post-movement period. Consequently, head movements should be adjusted to avoid the costly oscillations. Experimentally, such adjustments can be seen with time constants of about ten trials in healthy subjects but not in labyrinthine-defective patients. This indicates that the motor command either alone or together with the internal model of the head plant is modified using vestibular feedback. We discuss implications for possible mechanisms of optimization, adaptation and learning of novel plant characteristics.

INDIVIDUAL PRESENTATIONS V
Session 12

Friday, April 27
15:00 – 17:00

A novel computational approach helps explain and reconcile conflicting experimental findings on the neural control of arm endpoint stiffness

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Much debate has arisen from conflicting experimental findings of limb impedance control during reaching movements--particularly about neural regulation of stiffness and its energetic consequences. Some find that the eccentricity and orientation of arm endpoint stiffness ellipsoids can be tuned arbitrarily in response to unstable force fields during reaching movements [1-4]. Others come to nearly the opposite conclusion: that the ability of the nervous system to tune stiffness orientation is limited to around 30 degrees rotation, and also that the mechanical consequences of changes in arm posture are responsible for much of the changes in eccentricity and orientation [5-7]. We use novel theoretical analyses of tendon-driven systems and computational results to explain and reconcile these conflicting findings. Our unique formulation combining quadratic programming and vertex enumeration addresses the problem of synthesizing

arbitrary endpoint stiffness ellipsoids as a function of passive muscles stiffness and arm configuration. We use a 6-muscle planar arm model often used to simulate the relevant experiments [8-12]. We find that only when the endpoint is in the specific areas of the workspace where the Jacobian is well-conditioned can tuning the stiffness of both mono- and bi-articular muscles suffice to arbitrarily rotate the major axis of the endpoint stiffness ellipsoid. Moreover, the achievable rotations are sensitive to moment arm ratios of bi-articular muscles. As the hand moves away from these small well-conditioned areas, however, the mechanical ability to arbitrarily orient the ellipsoid decreases drastically. Thus, the potential for the nervous system to re-orient stiffness ellipsoids depends critically on the posture of the arm--and on the moment arm ratios of bi-articular muscles. Moreover, in the presence of coupling of muscle activity (specifically, the previously-reported synergies between bi-articular muscles and mono-articular elbow muscles [5]), the orientation of the ellipsoid can only be modified by changing one critical parameter: the ratio of elbow stiffness to shoulder stiffness. Even for broad ratios spanning two orders of magnitude (0.1 to 10), the range of orientation flexibility is limited to <90°--and compatible with the reported findings of limited orientation range. Thus, in fact, muscle synergies drastically reduce endpoint stiffness flexibility in any posture. Lastly, we find that in the absence of any synergies of neural origin, and for any desired and realizable endpoint stiffness matrix, there exists a well-defined one-dimensional manifold in muscle activations that can produce a given endpoint stiffness ellipsoid. Because there is some muscle redundancy to produce endpoint stiffness, that solution space provides some latitude to meet other functional criteria such as minimizing energetic cost. Thus, producing a given end-point stiffness ellipsoid is not necessarily synonymous with minimizing energetic cost as some studies suggest [1-4]. We show that energy cost can be reduced by up to 50% without affecting the stiffness ellipse, if no synergies exist. By enabling us to predict endpoint stiffness in arbitrary tendon-driven systems, our novel computational approach allows us to explain and reconcile conflicting experimental results, and design informative experiments to elucidate the neural strategies to learn and implement mechanical interactions with the physical world.

Unmasking reflexive control of the arm reaching

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The long tradition of classifying movements as reflexive or voluntary (programmed) is being challenged by the emerging view that most motor responses including reaching, are controlled automatically (Jeannerod 2006; Pockett 2006). However, the possible mechanisms of automatic control are disputable. Recent insights into the neural mechanism underlying behavior suggest the view of the brain as a highly dynamic wiring system able to create dedicated neural circuits for a practically unlimited variety of responses. One critical feature of these circuits is that the structure of the movement (that is, the movement parameters) is embedded in the patterns of the synaptic connections established through training-dependent wiring. Such circuits may be instantly activated by the proper sensory signal, resulting in the automatic generation of complex behavior without programming. Evidence for the presence of such circuits has been obtained by local electric stimulation inducing movements similar to the natural responses to a cue (du Lac and Knudsen 1990; Graziano et al 2002). Orderly arranged set of such motor circuits forms motor maps which receive projections from a sensory map representing the cue. It has been suggested that such mapping of sensory stimuli onto the structure of the movement provide a reliable mechanism for automatic control of large classes of responses ranging from orienting head movements to the production of speech (du Lac and Knudsen 1990; Guenter and Vladusich 2009). Here we present evidence that control of reaching may be based on the direct mapping of the spatial cues from the target onto the structure of the movement which bring the arm to correct location in space. Moreover, we show that the links between the sensory map representing the cues and motor map housing the structures of the responses is dynamic and active during movement execution. This makes it possible to achieve automatic control of the movement throughout its entire course directly by the signal from the cue, actually without the use of feedback. We tested

novel naturalistic paradigms of continuous arm tracking and prospective catching, with highly dynamic and unpredictable parameters of target motion in both tasks. In the tracking test, we showed that regardless of the complexity of the target motion, the hand can reproduce a complex and unpredictable trajectory of the target with shortest stable delay of about 100 ms. In the catching task, a rolling ball suddenly appeared in front of the subject, with highly variable inter-trial direction and velocity. We found that the trajectory of catching could be updated multiple times in-flight, with the interval between updates as short as 30 ms. Critically, the first update of the movement could be observed in a 30 ms after its onset, indicating that the central command for the update can be issued before the onset of overt movement, i.e. before generation of the error signal. These findings were neither predicted nor can be explained by the current motor control theory and indicate that there is direct tight link between the spatial signal from the cue and the circuits controlling the movements in space. As result the movement can be continuously guided by the signal from the cue. In sum, the data suggest that control of reaching is fundamentally reflexive, however, this has tended to be masked in sophisticated experimental paradigms that do not involve direct reaching to real targets.

Somatosensory perceptual training changes sensorimotor networks in the resting brain

David Ostry[1], Shahab Vahdat[1], Mohammad Darainy[1]

[1]McGill University

It has been recently shown that motor learning is accompanied by changes in perceptual function and associated changes in sensory areas of the brain. This has been demonstrated in studies of somatosensory function in human arm movement and in studies of auditory function in speech motor learning. We describe here a new set of studies of the effects of perceptual learning that suggest that the opposite may also be true — that is, perceptual training leads to changes in the extent of motor learning and also results in changes involving motor areas of the brain. We report on the results of two studies, one involving psychophysical measures and the other an fMRI study that examines changes in the resting brain following perceptual training. The behavioral study involved supervised perceptual training in which subjects held the handle of a robotic device that passively moved the arm outward in a horizontal plane on one of a set of fan-shaped paths that deviated from body midline by up to 8 deg. Subjects were required to judge whether the hand had been moved to the right or the left of the midline. Feedback on response accuracy was provided. The perceptual training trials were preceded and followed by movements in the absence of load. Movements in a velocity-dependent force field were also tested following the second set of null field movements (after perceptual training). A control group produced the same set of movements but did not undergo the perceptual training. We found that perceptual training resulted in changes in perceptual judgements (both in limb position and acuity). But, more importantly, we also found that perceptual training reduced the curvature of null field movements and increased the amount of force-field learning. Subjects that showed greater amounts of perceptual learning were found to learn more in subsequent force field trials. We studied the neural substrates of the these perceptual and motor effects by using fMRI to measure changes in the brain's resting-state networks as a result of perceptual learning. In this experiment subjects underwent scans of the resting brain before and after somatosensory perceptual training. Seed regions for functional connectivity analyses were obtained from a somatosensory perceptual judgement task that was run at the end of the second scanning session. We examined changes in functional connectivity between somatosensory seed-regions and those clusters of voxels whose correlation with the seed-region changed as a result of perceptual training. We found that perceptual training strengthened the correlation between regions of somatsensory cortex and motor areas of the brain. In particular, we found changes in connectivity in areas contralateral to the training arm, between BA3/2 and each of dorsal premotor cortex, primary motor cortex, and supplementary motor area. Overall, the results of our studies to date indicate that perceptual training alters motor learning and strengthens functional connectivity between somatosensory and motor areas of the brain.

Although our tests thus far have all used healthy young adults, the findings are encouraging for the use of robot-assisted therapy in patient populations.

Cortical foundations of human speech production

Kristofer Bouchard[1], Nima Mesgarani[1], Miranda Babiak[1], Keith Johnson[2], Edward Chang[1]

[1]University of California, San Francisco, [2]University of California, Berkeley

No behavior is as unique to humans as the ability to produce spoken language, and few behaviors that every human performs are as complicated to control as speech. Understanding the spatio-temporal organization of cortical signals that control the articulators of the vocal plant during the production of basic speech elements (consonants and vowels) is fundamental to our understanding of how the brain produces the complex sequence of movements that compose spoken language. We recorded neuro-electrical activity from the surface of speech somato-motor cortex using high-density electrocorticography (ECoG) in neurosurgical patients during the production of a large and expansive set of American English consonant-vowel (CV) syllables. These recordings revealed that different syllables are produced by the graded activation of multiple cortical sites in overlapping spatio-temporal patterns. Across subjects, we found that the functional temporal structure of speech somato-motor cortex is sequenced to first shape the upper vocal tract, through movement of the lips and tongue, filtering the sound produced at the larynx and released from the vocal tract by the jaw. Furthermore, the functional modulations of neuro-electrical activity underlying speech production are somatotopically organized, with both anatomically well isolated as well as overlapping representations of the speech articulators. Analysis of the spatial patterns of activity (neural state-space) at both consonant and vowel time point's reveals a hierarchically clustered structure that is primarily organized by the pattern of articulatory engagements. Finally, the neural state-space exhibits divergent and convergent dynamics that smoothly reflect the time dependent relationship between neural and articulatory states for both consonants and vowels. Together, our results lay the foundations of an electro-physiological understanding of speech production in humans. More generally, our results provide insight into how the human neocortex dynamically controls complex, multi-articulator behaviors, which is crucial to our understanding of basic nervous system function.

We recorded cortical EEG signals from the speech production area of the peri-central sulcus in three patients during production of CV syllables. We analyzed high-gamma band [85-175 Hz] (HG) power extracted from the raw EEG signal via the Hilbert transform. To understand the relationship between HG-power and the engagement of different articulators during speech production, we successfully leveraged the variability in both the mean HG-power and the articulatory state (described by a linguistically derived binary articulation matrix) associated with different CV's using both linguistically motivated and data driven approaches. To analyze the temporal sequence of events with which the engagement of individual articulators modulated HG-power we calculated the partial correlation between articulatory state and variations in HG-power. We revealed the somatotopic organization of HG-power by examining the spatial pattern of weights assigned by a general linear model description of HG-power in terms of the articulatory state. We used PCA, k-means & hierarchical clustering to analyze both the static and dynamic structure of the spatial patterns of activity. We quantified the dynamic relationship between neural and articulatory state-spaces and relate this to set-theoretic measures of neural state-space topology.

Preparatory fronto-occipital alpha phase and distributed cortical oscillations predict failures of cognitive control

Brett Clementz[1], Jordan Hamm[1], Kara Dyckman[1], Jennifer McDowell[1]

[1]University of Georgia

Cognitive control is required for correct performance on antisaccade tasks, including the ability to inhibit an externally driven ocular motor response (a saccade to a peripheral stimulus) in favor of an internally driven ocular motor goal (a saccade directed away from a peripheral stimulus). Cognitive control is typically defined as influence of higher-level (association cortical) brain regions on sensory and/or motor regions supporting successful behavioral performance. Even healthy and well-practiced humans occasionally produce errors during antisaccade tasks, but the mechanisms associated with such failures of cognitive control are uncertain. Most research on cognitive control failures focuses on post-stimulus processing, although a growing body of literature highlights a role of intrinsic brain activity in perceptual and cognitive performance. There have been suggestions from blood-flow-based functional neuroimaging studies in intact humans that patterns of frontal cortical activations support successful antisaccade performance, but the sluggishness of the bold signal limits the conclusions that can be drawn from such studies. As of yet, therefore, functional neuroimaging work in intact humans has not localized in brain space with sufficient temporal resolution from where such intrinsic signals originate. The current investigation used whole head dense array electroencephalography and distributed source analyses to examine brain oscillations across a wide frequency bandwidth in the period prior to antisaccade cue onset. The goal was to understand the spatio-temporal and frequency-specific neural activations that determine success and failure of cognitive control during antisaccade performance. Results highlight four important aspects of ongoing and preparatory brain activations that differentiate error from correct antisaccade trials: (i) ongoing oscillatory beta (20-30Hz) power in anterior cingulate prior to trial initiation (lower for error trials), (ii) instantaneous phase of ongoing alpha-theta (7Hz) in frontal and occipital cortices immediately before trial initiation (opposite between trial types), (iii) gamma power (35-60Hz) in posterior parietal cortex 100 ms prior to cue onset (greater for error trials), and (iv) phase locking of alpha (5-12Hz) in parietal and occipital cortices immediately prior to cue onset (lower for error trials). These findings extend recently reported effects of pre-trial alpha phase on perception to cognitive control processes, and help identify the cortical generators of such phase effects that predict error trials. This work compliments research on preparatory activities during antisaccade tasks among awake behaving primates by demonstrating that activity in specific frequency bands and cortical locations may determine behavioral manifestations of cognitive control in the motor system.

Functional connectivity of the frontal eye fields in humans and macaque monkeys investigated with resting-state fMRI

Stefan Everling[1], Ravi Menon[1], Joseph Gati[1], R. Matthew Hutchison[1]

[1]University of Western Ontario

Although the frontal eye field (FEF) has been identified in macaque monkeys and humans, practical constraints related to invasiveness and task-demands have limited a direct cross-species comparison of its functional connectivity. In this study, we used resting-state functional MRI data collected from both awake humans and anesthetized macaque monkeys to examine and compare the functional connectivity of the FEF. A seed-region analysis revealed consistent ipsilateral functional connections of the FEF with fronto-parietal cortical areas across both species. These included the intraparietal sulcus, dorsolateral prefrontal cortex, anterior cingulate cortex, and supplementary eye fields. The analysis also revealed greater lateralization of connectivity with the FEF in both hemispheres in humans than in monkeys. Cortical surface-based transformation of connectivity maps between species further corroborated the

remarkable similar organization of the FEF functional connectivity. The results support an evolutionarily preserved fronto-parietal system and provide a bridge for linking data from monkey and human studies.

PANEL Session 13
Saturday, April 28
8:00 – 10:15

Motor skill learning across model systems: Cortical-subcortical interactions

John Krakauer[1], Adrian Haith[1], Bence Olveczky[2], Jose Carmena[3], Rui Costa[4]

[1]Johns Hopkins University, [2]Harvard University, [3]UC Berkeley, [4]Champalimaud Center for the Unknown

New motor behaviors require the selection of complex sequences of actions that with practice are executed with increasing precision. Work across a number of model systems, primates (human and non-human), birds and rodents is beginning to elucidate the behavioral time course, the underlying computations, and the neural dynamics of action selection and motor skill acquisition. Adrian Haith will begin by introducing a framework for thinking about motor learning, and skill learning in particular. The majority of human learning research has focused on adaptation paradigms in which subjects must learn to compensate for a systematic perturbation to movement. Such learning is cerebellar-dependent and appears to be driven by updating an internal forward model of the motor apparatus and environment through sensory prediction errors. Recent results in humans suggest a parallel learning mechanism, likely dependent on motor cortex and the basal ganglia, in which learning occurs through repetition and reinforcement of successful actions. This model-free reinforcement-driven learning mechanism may underlie skill learning, which is best characterized in terms of reduction in variability and increase in success rate, rather than reduction in systematic error. Songbirds, with their learned courtship vocalization, offer a unique system in which to study complex motor learning. Bence Olveczky will highlight recent findings with relevance to mammalian motor learning, and discuss efforts to establish a rodent paradigm for motor skill learning with many of the advantages of the birdsong system. He will discuss the functional role of various brain areas in the acquisition and production of complex motor sequences elucidated through targeted brain lesions and reversible inactivations. Jose Carmena will show that closed-loop brain-machine interfaces (BMIs) provide a framework for studying cortical dynamics and the neural correlates of learning neuroprosthetic skills, i.e. accurate, readily-recalled control of disembodied actuators irrespective of natural physical movements. By monitoring ensembles of neurons from primary motor cortex (in monkey and rat) and dorsolateral striatum (in rat) he will show that the brain can consolidate prosthetic motor skill in a way that resembles natural motor learning and that corticostriatal plasticity is necessary for such learning. As action sequences are consolidated, behavior becomes more precise and neural variability decreases. Rui Costa will show that many neurons in basal ganglia develop sequence-related activity - e.g. related to the initiation, execution, and termination of the learned action sequences - suggesting that action sequences are processed as action units. This activity is differently expressed in specific cortico-basal ganglia subcircuits, and manipulating these circuits specifically using optogenetics affects different aspects of sequence performance. Furthermore, corticostriatal plasticity is critical for the shaping of novel actions into precise movement sequences.

PANEL Session 14

Saturday, April 28

10:45 – 12:15

Complex tasks with multiple solutions: A challenge for traditional motor control

Etienne Burdet[1], Dagmar Sternad[2], Andrea d'Avella[3], Ganesh Gowrishankar[4]

[1]Imperial College London, [2]Northeastern University, [3]Santa Lucia Foundation, [4]Kobe Advanced ICT Research Center, Biological ICT Group

Simple motor tasks such as reaching movements, force field learning, or movements through a via-point, feature a single optimum of error and effort, in which optimization has been computed using linear optimal control, nonlinear optimization with constraints or by gradient descent. Sub-optimality has been examined with respect to incomplete convergence to the unique optimum solution but rarely in a paradigm with distinct multiple optima. In contrast, many real life tasks are redundant and characterized by multiple solutions and hence distinct optima of error and effort. For instance, to prevent spilling Champagne from a glass when disturbed by a neighbor at a party, one can either stiffen one's arm to reduce the amplitude of its movement (i.e., a strategy requiring large muscle activations and effort), or conversely relax the arm (requiring less effort), leading to a larger movement but low hand acceleration. How does the human CNS deal with these tasks involving several solutions, and select between task satisfying solutions? Did we miss important insights about the working of the CNS when examining too simple experiments? This session will address these questions through complex tasks studied in recent years. In contrast to the traditional framework of motor control, in such tasks the CNS may utilize multiple solutions to solve one task. Etienne Burdet will first introduce the challenges and benefits offered by tasks with multiple solutions, followed by four presentations which will present such tasks and examine the computational mechanisms involved in motion planning, control and learning: First, Dagmar Sternad will examine how subjects carry a cup of coffee, which is a task presenting a manifold of solutions, especially when time constraints are relaxed. With practice, subjects converged to different solutions, though there are systematic dependencies between variability and energy margins within each individual. Andrea d'Avella will then show that when human subjects intercept a moving target in naturalistic conditions, they use motion patterns that are strikingly different across individuals with comparable task performance. Thus, there is no unique way to catch a flying ball and the individual CNS selects one of many available solutions to perform this task skilfully. Finally, Gowrishankar Ganesh will show that in the presence of multiple solutions, a simple strategy utilized by the CNS is to utilize motor memory and keep the previously successful solution. He will also present data demonstrating that motor memory affects not just motor execution but also motion planning. The discussion will focus on examining the strategies humans use to control complex tasks with many solutions. It will examine possible frameworks for these novel findings, and additional variables/factors that may need to be used in addition to error and effort in order to explain behaviour in tasks with multiple solutions.

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- Neural and Rehabilitation Engineering
- Cellular and Tissue Engineering and Biomaterials
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Poster Session 1 | By Author Name

All posters in Session 1 will be on display in Venetian Ballroom A & B and the Foyer as follows:
Tuesday, April 24, 8:00 – 17:15 • Wednesday, April 25, 8:00 – 17:20

Poster Session 1a
If the last part of your poster number (i.e. board number) is ODD, your dedicated poster session is **Tuesday, April 24**, 13:00 - 15:00. Please be at your poster during this time.

Poster Session 1b
If the last part of your poster number (i.e. board number) is EVEN, your dedicated poster session is **Wednesday, April 25**, 12:45 - 14:30. Please be at your poster during this time.

Themes
A - Adaptation & Plasticity in Motor Control
B - Integrative Control of Movement
C - Control of Eye & Head Movement
D - Disorders of Motor Control
E - Posture & Gait
F - Fundamentals of Motor Control
G - Theoretical & Computational Motor Control

Author	Session	Theme	Board*	Poster No.
Acher, A	1	A	19	1-A-19
Anzak, A	1	F	52	1-F-52
Apker, G	1	G	83	1-G-83
Arellano, C	1	C	62	1-C-62
Barany, D	1	A	15	1-A-15
Bassolino, M	1	A	12	1-A-12
Beloozerova, I	1	C	31	1-C-31
Beraneck, M	1	A	22	1-A-22
Berniker, M	1	A	2	1-A-2
Berret, B	1	G	76	1-G-76
Boisgontier, M	1	F	33	1-F-33
Bongers, R	1	A	3	1-A-3
Boonstra, T	1	F	34	1-F-34
Brown, L	1	B	92	1-B-92
Buckingham, G	1	F	49	1-F-49
Carretero, A	1	G	84	1-G-84
Casellato, C	1	D	106	1-D-106
Choi, J	1	E	75	1-E-75
Chu, V	1	E	70	1-E-70
Cos, I	1	B	89	1-B-89
Cramer, S	1	F	41	1-F-41
Dagioglou, M	1	A	27	1-A-27
Dayanidhi, S	1	B	90	1-B-90
De Sanctis, T	1	B	96	1-B-96
Delhaye, B	1	F	48	1-F-48
Delis, I	1	G	77	1-G-77
Feinman, A	1	B	98	1-B-98
Francis, J	1	G	85	1-G-85
Fu, Q	1	A	5	1-A-5
Gail, A	1	B	105	1-B-105
Gaveau, V	1	F	56	1-F-56
Ghoreyshi, A	1	G	80	1-G-80
Giard, T	1	F	47	1-F-47
Grandi, L	1	B	100	1-B-100
Granek, J	1	B	93	1-B-93
Hadjiosif, A	1	G	81	1-G-81
Hagura, N	1	B	99	1-B-99
Haji Abolhassani, I	1	C	59	1-C-59
Hall, T	1	B	97	1-B-97
Hasson, C	1	G	78	1-G-78
Herrojo Ruiz, M	1	A	14	1-A-14
Herz, D	1	B	101	1-B-101
Hewitt, A	1	A	25	1-A-25
Hinder, M	1	A	28	1-A-28
Hirashima, M	1	A	17	1-A-17
Howard, I	1	A	24	1-A-24
Humbert, I	1	A	4	1-A-4
Idoux, E	1	C	65	1-C-65
Ikegami, T	1	F	42	1-F-42
Ingram, J	1	G	86	1-G-86
Inoue, Y	1	F	43	1-F-43
Ito, N	1	C	57	1-C-57
Ivanenko, Y	1	E	74	1-E-74
Jalaleddini, K	1	E	72	1-E-72
Kaski, D	1	A	10	1-A-10
Kassavetis, P	1	A	13	1-A-13
Kaufman, M	1	F	37	1-F-37
Koch, G	1	B	102	1-B-102
Komeilipoor, N	1	F	50	1-F-50
Kristeva, R	1	F	55	1-F-55
Kukke, S	1	F	46	1-F-46
Lawrence, E	1	F	53	1-F-53
Lemos, T	1	E	71	1-E-71
MacLellan, M	1	E	73	1-E-73
Makin, T	1	A	18	1-A-18
Medendorp, P	1	C	60	1-C-60
Mustari, M	1	C	64	1-C-64
Nasir, S	1	A	7	1-A-7
Nasir, S	1	A	8	1-A-8
Oliveira, L	1	F	44	1-F-44
Onneweer, B	1	A	1	1-A-1
Oostwoud Wijdenes, L	1	F	38	1-F-38
Pai, D	1	C	32	1-C-32
Paige, G	1	C	58	1-C-58
Panouilleres, M	1	A	30	1-A-30
Pitcher, J	1	A	16	1-A-16
Popa, L	1	F	39	1-F-39
Pope, P	1	A	20	1-A-20
Pozzo, T	1	C	66	1-C-66
Ranjbaran Hesarmaskan, M	1	C	61	1-C-61
Riehle, A	1	B	95	1-B-95
Rodrigues, E	1	A	23	1-A-23
Sadnicka, A	1	F	40	1-F-40
Sanchez, J	1	F	35	1-F-35
Saucedo, C	1	A	9	1-A-9
Sayegh, P	1	B	94	1-B-94
Scheidt, R	1	A	21	1-A-21
Seki, K	1	F	51	1-F-51
Soekadar, S	1	A	11	1-A-11
Squeri, V	1	B	104	1-B-104
Sternad, D	1	G	82	1-G-82
Taylor, J	1	G	88	1-G-88
Terekhov, A	1	F	36	1-F-36
Terekhov, A	1	G	79	1-G-79
Togo, S	1	B	103	1-B-103
Trent, M	1	A	29	1-A-29
Tsakiris, D	1	E	69	1-E-69
van der Smagt, P	1	B	91	1-B-91
van Opstal, J	1	C	63	1-C-63
Vargas-Irwin, C	1	G	87	1-G-87
Vernooij, C	1	F	54	1-F-54
Verrel, J	1	E	68	1-E-68
Voudouris, D	1	F	45	1-F-45
Wiestler, T	1	A	26	1-A-26
Willigenburg, N	1	E	67	1-E-67
Winges, S	1	A	6	1-A-6

Board locations are shown on the Poster Session Floor Plans (inside back cover).

Poster Session 2 | By Author Name

All posters in Session 2 will be on display in Venetian Ballroom A & B and the Foyer as follows:
Friday, April 27, 8:00 – 17:00   •   Saturday, April 28, 8:00 – 15:00

Poster Session 2a
If the last part of your poster number (i.e. board number) is ODD, your dedicated poster session is **Friday, April 27**, 12:45 - 15:00. Please be at your poster during this time.

Poster Session 2b
If the last part of your poster number (i.e. board number) is EVEN, your dedicated poster session is **Saturday, April 28**, 12:15 - 14:00. Please be at your poster during this time.

Themes
A - Adaptation & Plasticity in Motor Control
B - Integrative Control of Movement
D - Disorders of Motor Control
F - Fundamentals of Motor Control
G - Theoretical & Computational Motor Control

Author	Session	Theme	Board*	Poster Number
Ahmed, A	2	A	12	2-A-12
Anderson, J	2	D	91	2-D-91
Baraduc, P	2	G	78	2-G-78
Beloozerova, I	2	F	57	2-F-57
Berger, D	2	A	18	2-A-18
Bertucco, M	2	D	86	2-D-86
Bodison, S	2	D	92	2-D-92
Borzelli, D	2	F	31	2-F-31
Bosco, G	2	B	39	2-B-39
Bourns, K	2	A	17	2-A-17
Buch, E	2	A	11	2-A-11
Burgos, P	2	A	16	2-A-16
Cantarero, G	2	A	10	2-A-10
Cesqui, B	2	B	34	2-B-34
Cheng, D	2	F	56	2-F-56
Cheyne, D	2	B	37	2-B-37
D' Andola, M	2	B	38	2-B-38
Danion, F	2	A	21	2-A-21
Davare, M	2	F	61	2-F-61
David, F	2	D	82	2-D-82
de Boer, B	2	F	62	2-F-62
Debats, N	2	G	64	2-G-64
Dessing, J	2	G	67	2-G-67
Diedrichsen, J	2	A	19	2-A-19
Dimitriou, M	2	B	35	2-B-35
Franklin, S	2	B	36	2-B-36
Franquemont, L	2	F	32	2-F-32
Glasauer, S	2	A	27	2-A-27
Gretenkord, S	2	A	8	2-A-8
Hamada, M	2	A	22	2-A-22
Hammerbeck, U	2	B	46	2-B-46

Author	Session	Theme	Board*	Poster Number
Hardwick, R	2	A	1	2-A-1
Hart, C	2	G	74	2-G-74
Hawkins, K	2	D	81	2-D-81
Hermosillo, R	2	F	58	2-F-58
Hoad, D	2	A	23	2-A-23
Huberdeau, D	2	G	68	2-G-68
Jörntell, H	2	B	42	2-B-42
Kawai, R	2	F	50	2-F-50
Kennedy, J	2	A	15	2-A-15
Kim, G	2	B	41	2-B-41
Laczko, J	2	F	51	2-F-51
Leal Campanario, R	2	B	47	2-B-47
Lemme, A	2	G	76	2-G-76
Levy, G	2	F	52	2-F-52
López Ramos, J	2	A	24	2-A-24
Lunardini, F	2	D	85	2-D-85
Lytton, W	2	A	26	2-A-26
Maij, F	2	G	75	2-G-75
Malfait, N	2	B	45	2-B-45
Marino, H	2	G	66	2-G-66
Márquez-Ruiz, J	2	A	5	2-A-5
Mattia, M	2	G	69	2-G-69
Miyamoto, Y	2	A	25	2-A-25
Murcia-Belmonte, V	2	B	48	2-B-48
Nazarpour, K	2	G	77	2-G-77
Nesher, N	2	F	53	2-F-53
Nilsson, M	2	A	14	2-A-14
Niu, C	2	D	88	2-D-88
Nogueira-Campos, A	2	F	30	2-F-30
Pastor, D	2	A	13	2-A-13
Patanè, L	2	A	7	2-A-7

Author	Session	Theme	Board*	Poster Number
Puentes Martinez, S	2	D	87	2-D-87
Reichenbach, A	2	B	43	2-B-43
Roby-Brami, A	2	D	89	2-D-89
Rueda-Orozco, P	2	F	63	2-F-63
Russo, M	2	F	29	2-F-29
Sachs, N	2	F	60	2-F-60
Sarlegna, F	2	A	3	2-A-3
Sartori, L	2	F	54	2-F-54
Scherberger, H	2	F	49	2-F-49
Schofield, C	2	A	6	2-A-6
Semprini, M	2	G	65	2-G-65
Smeets, J	2	A	4	2-A-4
Smith, M	2	G	72	2-G-72
Sylaidi, A	2	F	55	2-F-55
Sylos Labini, F	2	G	79	2-G-79
Taylor, S	2	G	71	2-G-71
Todorov, E	2	G	80	2-G-80
Uecker, J	2	G	70	2-G-70
van Beers, R	2	A	2	2-A-2
van der Steen, M	2	G	73	2-G-73
Vidal, P	2	B	44	2-B-44
Vigaru, B	2	F	28	2-F-28
Wong, J	2	A	9	2-A-9
Yaguchi, H	2	F	59	2-F-59
Yeo, S	2	B	40	2-B-40
Yokoi, A	2	A	20	2-A-20
Young, S	2	D	84	2-D-84
Zangemeister, W	2	D	90	2-D-90
Zeharia, N	2	B	33	2-B-33
Zimmermann, J	2	D	83	2-D-83

*Board locations are shown on the Poster Session Floor Plans (inside back cover).

Poster Sessions | Authors, Titles and Affiliations

Session 1   Posters are listed by theme.

A - Adaptation & Plasticity in Motor Control

1-A-1   Paradoxical arm stiffness: Humans actively reduce endpoint arm stiffness in force tasks

Bram Onneweer[1], Erwin de Vlugt[1], Alfred C Schouten[1], Winfred Mugge[1], Carel G.M. Meskers[2], Frans C. T. van der Helm[1]

[1]TU Delft, [2]Leiden University Medical Center

1-A-2   Internal model reference frames and generalizability

Max Berniker[1], Konrad Kording[1]

[1]Northwestern University

1-A-3   Properties of a grasping tool affect grasping behavior

Raoul Bongers[1], Leonoor J Mouton[1], Frank Zaal[1]

[1]University of Groningen

1-A-4   Oral and pharyngeal sensory processing have differential control over hyo-laryngeal kinematics

Ianessa Humbert[1], Akshay Lokhande[1], Heather Christopherson[1], Rebecca German[1], Alice Stone[1]

[1]Johns Hopkins University

1-A-5   Interference between geometric cues and sensorimotor memories for anticipatory control of manipulation

Qiushi Fu[1], Marco Santello[1]

[1]Arizona State University

1-A-6   Patterns of hand muscle activation in pianists: From amateur to expert

Sara Winges[1], Shinichi Furuya[1], Martha Flanders[1]

[1]University of Minnesota

1-A-7   Neural correlates of sensory plasticity following motor learning

Sazzad Nasir[1], Mohammad Darainy[2], David J Ostry[2]

[1]Northwestern University, [2]McGill University

1-A-8   Sensory preference in speech motor learning revealed by simultaneous alteration of auditory and somatosensory feedback

Sazzad Nasir[1], Daniel R Lametti[2], David J Ostry[2]

[1]Northwestern University, [2]McGill University

1-A-9   Task-specific effect of transcranial direct current stimulation on motor learning

Cinthia Saucedo[1], Xue Zhang[1]

[1]K.U. Leuven

1-A-10 Enhanced locomotor adaptation after-effect in the 'broken escalator' phenomenon using anodal tDCS

Diego Kaski[1], Shamim Quadir[1], Nada Yousif[1], Adolfo M Bonstein[1]

[1]Imperial College London

1-A-11 Enhancing voluntary control of neural oscillatory activity driving a brain-machine interface (BMI)

Surjo Soekadar[1], Matthias Witkowski[1], Niels P Birbaumer[1], Leonardo G Cohen[2]

[1]University of Tübingen, [2]NINDS / National Institutes of Health

1-A-12 How action shapes space and body representations

Michela Bassolino[1], Alessandra Finisguerra[1], Andrea Serino[2], Thierry Pozzo[1]

[1]Istituto Italiano di Tecnologia, [2]CsrNC, Centro studi e ricerche in Neuroscienze Cognitive

1-A-13 Adaptation of surround inhibition in the human motor system

Panagiotis Kassavetis[1], Tabish A Saifee[1], Anna Sadnicka[1], Isabel Pareés[1], Maja Kojovic[1], John C Rothwell[1], Mark J Edwards[1]

[1]University College London, Institute of Neurology

1-A-14 Transitions between finger keypresses during acquisition of novel piano sequences are related to patterns of low frequency local field potential activity in the human globus pallidus internus

Maria Herrojo Ruiz[1], Christof Brücke[1], Gerd-Helge Schneider[1], Andrea A Kühn[1]

[1]Charité - University of Medicine

1-A-15 Limited visuomotor adaptation to variable amplitude gains within a movement trajectory

Deborah Barany[1], Shivakumar Viswanathan[1], Scott T. Grafton[1]

[1]University of California, Santa Barbara

1-A-16 Physiological evidence of reduced neuroplasticity in human adolescents who were born preterm

Julia Pitcher[1], Alysha M Riley[1], Michael C Ridding[1]

[1]University of Adelaide

1-A-17 The presence of multiple potential visual targets affects the retrieval of motor memory for a reaching movement

Masaya Hirashima[1], Daichi Nozaki[1], Gaku D Yamawaki[1]

[1]The University of Tokyo

1-A-18 Plasticity in amputees: Reorganization in somatosensory and motor cortices varies with adaptive strategies for limb use

Tamar Makin[1], Jan Scholz[2], Nicola Filippini[1], David Henderson Slater[4], Irene Tracey[1], Heidi Johansen-Berg[1]

[1]Oxford University, [2]Hospital for Sick Children, [4]Nuffield Orthopaedic Centre

1-A-19 Cortical networks involved in speech recovery after glossectomy: Preliminary results of an fMRI study

*Audrey Acher*[1], Marc Sato[1], Laurent Lamalle[2], Coriandre Vilain[1], Alexandre Krainik[2], Pascal Perrier[1]

[1]Gipsa-lab - UMR CNRS 5216, [2]CHU de Grenoble

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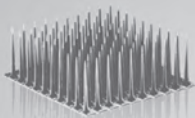
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1-A-20 Comparing neural activity for repetitive finger and foot movements in cerebellar patients and healthy controls reveals lesion induced changes in specific regions of cortex

Paul Pope[1], Roxana Burciu[2], Maria Dagioglou[1], Nina Theysohn[2], R Chris Miall[1], Dagmar Timmann[2]

[1]University of Birmingham, [2]University of Duisburg-Essen

1-A-21 Learning finger coordination patterns by altering dimensionality

Robert Scheidt[1], Rajiv Ranganathan[2], Jon A Wieser[1], Kristine M Mosier[4], Ferdinando A Mussa-Ivaldi[2]

[1]Marquette University, [2]Rehabilitation Institute of Chicago, [4]Indiana University School of Medicine

1-A-22 Ontogeny of vestibulo-ocular reflex following genetic or environmental alteration of gravity-perception

Mathieu Beraneck[1], Mickael Bojados[2], Anne Le Séach[1], Marc Jamon[2], Pierre-Paul Vidal[1]

[1]CNRS - University Paris Descartes, [2]Aix-Marseille Univ, UMR 1106

1-A-23 The impact of limb agenesis on brain structure

Erika Rodrigues[1], Fernanda Tovar-Moll[2], Ivanei Bramati[2], Claudia Vargas[3], Jorge Moll[2], Angela Sirigu[4]

[1]Augusto Motta University Center (UNISUAM), [2]D Or Institute for Research and Education (IDOR), [3]Federal University of Rio de Janeiro, [4]Center for Cognitive Neuroscience

1-A-24 Recent action determines the encoding of motor memory

Ian Howard[1], David W Franklin[1], James N Ingram[1], Daniel M Wolpert[1]

[1]University of Cambridge

1-A-25 Adaptation to force perturbations alters feedforward and feedback signals in Purkinje cell simple spike firing

Angela Hewitt[1], Laurentiu S Popa[1], Timothy J Ebner[1]

[1]University of Minnesota

1-A-26 Motor learning increases the distinctiveness of cortical sequence representations: Evidence from multi-voxel pattern analysis

Tobias Wiestler[1], Jörn Diedrichsen[1]

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1-A-27 The effect of acquisition of an internal forward model on an exploration task

Maria Dagioglou[1], Joaquin Bugella[1], Tom Walton[2], Tom Stafford[2], Peter Redgrave[2], Chris Miall[1]

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1-A-28 Transfer of ballistic motor skills between bilateral and unilateral contexts in young and older adults: Neural adaptations and behavioural implications

Mark Hinder[1], Timothy J Carroll[2], Jeffery J Summers[1]

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1-A-29 Risk-sensitivity in motor learning

Michael Trent[1], Alaa A Ahmed[1]

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1-A-30 Our brain sees and learns during fast eye movements

Muriel Panouilleres[1], Valérie Gaveau[1], Christian Urquizar[1], Denis Pelisson[1]

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B - Integrative Control of Movement

1-B-89 A study of the influence of biomechanics on decisions between reaching movements

Ignasi Cos[1], Paul Cisek[1]

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1-B-90 Measurable improvements in dexterous manipulation throughout adolescence reveal previously undetected functional effects of neuromaturation

Sudarshan Dayanidhi[1], Åsa Hedberg[2], Francisco J Valero-Cuevas[1], Hans Forssberg[2]

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1-B-91 Identification of human limb impedance in 5 DoF

Patrick van der Smagt[1], Dominic Lakatos[1], Daniel Rüschen[1], Jörn Vogel[1]

[1]DLR / RM

1-B-92 Simulated hemianopia drives eyes to distraction

Liana Brown[1], Carina La Mantia[1]

[1]Trent University

1-B-93 Different brain pathways for strategic control versus sensorimotor recalibration: Evidence from a dual task reach paradigm

Joshua Granek[1], Lauren E Sergio[1]

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1-B-94 Separating standard and non-standard reaches: Topographical differences within PMd

Patricia Sayegh[1], Kara M Hawkins[1], Lauren E Sergio[1]

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1-B-95 Mapping the spatio-temporal structure of motor cortical LFP and spiking activity during reach and grasp movements

Alexa Riehle[1], Thomas Brochier[1]

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1-B-96 Reach to grasp movements: A combined EEG and kinematic study

Teresa De Sanctis[1]

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1-B-97 On the relationship between spiking activity and low-frequency local field potentials in primate motor cortex

Thomas Hall[1], Kianoush Nazarpour[1], Andrew Jackson[1]

[1]University of Newcastle-upon-Tyne, UK

1-B-98 Nonlinear EMG estimation as a control signal in a one-muscle myocontrol task

Adam Feinman[1], Terence D Sanger[1]

[1]University of Southern California

1-B-99 When to move and how to move: Information about the movement type and the timing of movement are concurrently processed in the human motor system

Nobuhiro Hagura[1], Yosuke Goto[2], Michikazu Matsumura[2]

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1-B-100 Hand-related sensory-motor activity in secondary somatosensory cortex of the macaque monkey

Laura Grandi[1], Hiroaki Ishida[2], Luca Fornia[1], Vittorio Gallese[2]

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1-B-101 Improved control over impulsive but inappropriate response tendencies following 1 Hz repetitive TMS of pre-supplementary motor area

Damian Herz[1], Hartwig R Siebner[1], Mark S Christensen[1], Norbert Bruggemann[1], Brian N Haagensen[1], Kristoffer H Madsen[1]

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1-B-102 Intra-hemispheric parietal-motor paired associative stimulation induces bidirectional plasticity

Giacomo Koch[1], Domenica Veniero[1], Francesco Di Lorenzo[1], Carlo Caltagirone[1]

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1-B-103 UCM analysis of human multi-joint coordination and mechanical arm impedance

Shunta Togo[1], Takahiro Kagawa[1], Yoji Uno[1]

[1]Nagoya University

1-B-104 Two hands, one perception: Bimanual integration of haptic information

Valentina Squeri[1], Alessandra Sciutti[1], Monica Gori[1], Lorenzo Masia[1], Giulio Sandini[1], Juergen Konczak[2]

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1-B-105 Predicting sensory consequences of intended movements in monkey posterior parietal cortex

Alexander Gail[1], Shenbing Kuang[1]

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C - Control of Eye & Head Movement

1-C-31 Where cats look during walking

I*rina Beloozerova*[1], Trevor J Rivers[1], Mikhail G Sirota[1], Neet A Shah[1], Andrew I Guttentag[1], Dmitri A Ogorodnikov[2]

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1-C-32 Robotic models for neural control of eye movements

Dinesh Pai[1], Martin Lesmana[1], Per-Erik Forssén[2]

[1]University of British Columbia, [2]Linköping University

1-C-57 Smooth pursuit eye movement (SPEM) in patients with idiopathic Parkinson's disease (PD): Movement preparation and execution is impaired but not visual motion working memory

Norie Ito[1], Nozomi Tamaki[1], Ayumi Masuno[1], Kunihiro Ikeno[1], Sachiyo Onishi[1], Nobuyoshi Kobayashi[1], Hidetoshi Takei[1], Peter M Olley[1], Susumu Chiba[1], Kiyoharu Inoue[1], Grahamu Barnes[2], Kikuro Fukushima[1], Tateo Warabi[1]

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1-C-58 Oculomotor adaptation of sound localization depends upon the temporal relationship between targets and eye movements

Gary Paige[1], Emily C Clark[1], William O'Neill[1]

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1-C-59 Comparing models for eye-head trajectory interactions during head-free gaze shifts

Iman Haji Abolhassani[1], Daniel Guitton[2], Henrietta L Galiana[1]

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1-C-60 Testing effector-specificity of human posterior parietal cortex for eye, hand and foot movements: A multivariate analysis

Pieter Medendorp[1], Frank T Leone[1], Ivan I Toni[1], Tobias Heed[2]

[1]Radboud Univ Nijmegen, [2]University of Hamburg

1-C-61 A nonlinear model of the horizontal Angular Vestibulo-Ocular Reflex (AVOR) - A mechanism for context-dependent responses

Mina Ranjbaran Hesarmaskan[1], Henrietta L Galiana[1]

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1-C-62 Analysis of visual behavior in a continuous visual-motor coordination task

Cristian Arellano[1], Pablo Burgos[1], Pedro Maldonado[1]

[1]University of Chile

1-C-63 Dynamic probabilistic control of audiovisual saccades

John van Opstal[1], Marc Van Wanrooij[2], Brian Corneil[4], Doug Munoz[4]

[1]Donders Institute, [2]Radboud University Nijmegen, [4]University of Western Ontario, [4]Queens University

1-C-64 Properties of FEF projection neurons in smooth pursuit

Michael Mustari[1]

[1]University of Washington

1-C-65   Adaptation of intrinsic and synaptic properties of medial vestibular neurons during visual-vestibular mismatch

Erwin Idoux[1], Daniel Eugène[1], Antoine Mialot[1], Mathieu Beraneck[1]

[1]Université Paris Descartes

1-C-66   When the hand drives the eye: Hand-eye coordination when reaching to a manifold

Thierry Pozzo[1], Ambra Bisio[1], Marco Jacono[1], Bastien Berret[1]

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D - Disorders of Motor Control

1-D-106   EMG-based visual-haptic biofeedback: A promising tool to improve motor control in dystonia

Claudia Casellato[1], Giovanni Zorzi[2], Alessandra Pedrocchi[1], Giancarlo Ferrigno[1], Nardo Nardocci[2]

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E - Posture & Gait

1-E-67   Effects of low back pain and proprioception disturbance on precision of trunk control

Nienke Willigenburg[1], Idsart Kingma[1], Jaap H van Dieen[1]

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1-E-68   Persistence of motor-equivalent fluctuations during quiet standing

Julius Verrel[1], Didier Pradon[1], Nicolas Vuillerme[1]

[1]MPI for Human Development

1-E-69   Swimming patterns of the Octopus vulgaris

Dimitris Tsakiris[1], Asimina Kazakidi[1], Michael Kuba[2], Alex Botvinnik[2], Michael Sfakiotakis[1], Tamar Gutnick[2], Shlomi Hanassy[2], Guy Levy[2], John A Ekaterinaris[3], Tamar Flash[4], Binyamin Hochner[2]

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1-E-70   Reflex control of treadmill walking in subjects with spinal cord injury

Virginia Way Tong Chu[1], Thomas G Hornby[2], Brian D Schmit[3]

[1]Rehabilitation Institute of Chicago, [2]University of Illinois at Chicago, [3]Marquette University

1-E-71   Motor resonance during postural imbalance observation

Thiago Lemos[1], Banty Tia[2], Ghislain Saunier[1], Sebastian Hofle[1], Luís A Imbiriba[1], Thierry Pozzo[3], Claudia D Vargas[1]

[1]Universidade Federal do Rio de Janeiro, [2]Université de Bourgogne, [3]Université de Bourgogne and Italian Institute of Technology

1-E-72   Characterization of the nonlinearity in ankle reflex stiffness dynamics

Kian Jalaleddini[1], Ehsan Sobhani-Tehrani[1], Robert E. Kearney[1]

[1]McGill Univerisity

1-E-73   Decoupling of upper and lower limb central pattern generators during human crawling may highlight the influence of cortical control on the upper limb

Michael MacLellan[1], Yuri P Ivanenko[1], Valentina La Scaleia[1], Francesco Lacquaniti[1]

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1-E-74   Changes in the spinal motor output for stepping during development from infant to adult

Yuri Ivanenko[1], Nadia Dominici[1], Germana Cappellini[1], Ambrogio Di Paolo[2], Carlo Giannini[3], Richard E Poppele[4], Francesco Lacquaniti[2]

[1]Santa Lucia Foundation, [2]University of Rome Tor Vergata, [3]Sant'Eugenio Hospital, [4]University of Minnesota

1-E-75   Error-signals driving locomotor adaptation: Effects of peripheral nerve stimulation on ankle control during walking in an elastic force field

Julia Choi[1], Jesper Lundbye-Jensen[1], Laurent J Bouyer[2], Jens Bo Nielsen[1]

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F - Fundamentals of Motor Control

1-F-33   Effects of ageing on attentional cost and internal models of proprioceptive control of movement

Matthieu P. Boisgontier[1], Isabelle Olivier[1], Vincent Nougier[1]

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1-F-34   Mechanisms of oscillatory drive in human motor control

Tjeerd Boonstra[1], Michael Breakspear[1]

[1]University of New South Wales

1-F-35   Linking motor and reward: The correlation between nucleus accumbens and primary motor cortex during goal directed reaching

Justin Sanchez[1], Eric Pohlmeyer[1], Babak Mahmoudi[1], Shijia Geng[1], Noeline Prins[1]

[1]University of Miami

1-F-36   Haptic illusions: A window into motor control

Alexander Terekhov[1], Vincent Hayward[1]

[1]Université Pierre et Marie Curie

1-F-37   Controlling output from the motor cortices: Avoiding unintentional movement using the null space

Matthew Kaufman[1], Mark M Churchland[2], Stephen I Ryu[3], Krishna V Shenoy[1]

[1]Stanford University, [2]Columbia University, [3]Palo Alto Medical Foundation

1-F-38   Removing motion information reduces the latency of manual movement corrections

Leonie Oostwoud Wijdenes[1], Eli Brenner[1], Jeroen Smeets[1]

[1]VU University Amsterdam

1-F-39   Individual Purkinje cell simple spike discharge is full of errors

Laurentiu Popa[1], Angela L Hewitt[1], Timothy J Ebner[1]

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1-F-40   Modulation of cerebellar function does not affect the timing or magnitude of motor surround inhibition

Anna Sadnicka[1], Panagiotis Kassavetis[1], John C Rothwell[1], Mark J Edwards[1]

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1-F-41   Excitatory amino acid transporters regionally sculpt the beam-like response in the cerebellar cortex

Samuel Cramer[1], Wangcai Gao[1], Gang Chen[1], Timothy J Ebner[1]

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1-F-42   Tool kinematics planning in humans

Tsuyoshi Ikegami[1], Gowrishankar Ganesh[1]

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1-F-43   Intermittency in visual information acquisition in continuous tracking task

Yasuyuki Inoue[1], Yutaka Sakaguchi[1]

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1-F-44   Preparing to grasp pleasant and unpleasant objects

Laura Oliveira[1], Luis Aureliano Imbiriba[2], Maitê Mello Russo[1], Erika de Carvalho Rodrigues[3], Anaelli Aparecida Nogueira-Campos[1], Mirtes Garcia Pereira[4], Eliane Volchan[1], Cláudia Domingues Vargas[1]

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1-F-45   Do humans prefer to see their grasping points?

Dimitris Voudouris[1], Eli Brenner[1], Jeroen BJ Smeets[1]

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1-F-46   Cortical silent period duration and its implications for surround inhibition of a hand muscle

Sahana Kukke[1], Brach Poston[1], Rainer Paine[1], Sophia Francis[2], Mark Hallett[1]

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1-F-47   Grip force control strategies during slow load variations

Thibault Giard[1], Jean-Louis Thonnard[1], Philippe Lefèvre[1]

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1-F-48   Tactile detection of slip: Fine characterization of skin deformation during the onset of slip

Benoit Delhaye[1], Philippe Lefèvre[2], Jean-Louis Thonnard[1]

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1-F-49   Observing lifting errors modulates cortico-spinal excitability

Gavin Buckingham[1], Jeremy D Wong[1], Paul L Gribble[1], Melvyn A Goodale[1]

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1-F-50   Asymmetrical Modulation of corticospinal excitability as a function of emotional sounds along with ear laterality

Naeem Komeilipoor[1], Fabio Pizzolato[1], Andreas Daffertshofer[2], Paola Cesari[1]

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1-F-51   A neural basis for hand muscle synergy in primate spinal cord

Kazuhiko Seki[1], Tomohiko Takei[1]

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1-F-52   A neural correlate of arousal in the subthalamic nucleus facilitates force production

Anam Anzak[1], Alek Pogosyan[1], Huiling Tan[1], Thomas Foltynie[2], Patricia Limousin[2], Ludvic Zrinzo[2], Marwan Hariz[2], Keyoumars Ashkan[3], Wesley Thevathasan[1], Marko Bogdanovic[1], Alexander Green[1], Tipu Aziz[1], Peter Brown[1]

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1-F-53   Dynamic control of lower extremities declines with aging

Emily Lawrence[1], Veronica Stern[1], Mark Lyle[1], Carolee Winstein[1], Philip Requejo[2], Francisco J Valero-Cuevas[1]

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1-F-54   Artificially evoking physiological finger tremor suggests mechanical origin

Carlijn Vernooij[1], Raymond F Reynolds[1], Martin D Lakie[1]

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1-F-55   Stochastic resonance improves sensorimotor performance of the finger

Rumyana Kristeva[1], Ignacio Mendez-Balbuena[1], Elias Manjarrez[1], Juergen Schulte-Moenting[2], Frank Huethe[1], Joshua A Tapia[3], Marie-Claude Hepp-Reymond[4]

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1-F-56   Movement automatic guidance by direct internal model

Valerie Gaveau[1], Olivier Sillan[1], Calude Prablanc[1]

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G - Theoretical & Computational Motor Control

1-G-76 Methods for the study of modularity in muscle activities: A unifying model for extracting spatial and temporal modules from EMG signals

Bastien Berret[1], Ioannis Delis[1], Stefano Panzeri[1], Thierry Pozzo[1]

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1-G-77 Methods for the study of modularity in muscle activities: A single-trial task-decoding metric to evaluate muscle synergy models

Ioannis Delis[1], Bastien Berret[1], Thierry Pozzo[1], Stefano Panzeri[1]

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1-G-78 Safety margins and variability in a redundant object manipulation task

Christopher Hasson[1], Dagmar Sternad[1]

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1-G-79 Can we learn what the brain optimizes?

Alexander Terekhov[1], Vincent Hayward[2]

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1-G-80 Implementation of stochastic feedback control and Bayesian nonlinear filtering in spiking neuron populations

Atiyeh Ghoreyshi[1], Terence Sanger[1]

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1-G-81 Learning rate modulation vs. dimensionality reduction as a mechanism for structural learning

Alkis Hadjiosif[1], Maurice A Smith[1]

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1-G-82 Augmentation of perceived visual error improves control and enhances retention of a discrete task

Dagmar Sternad[1], Meghan E Huber[1], Anastasia Kyvelidou[1]

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1-G-83 Interaction of sensory uncertainty and motor variability during reaching: A simulation study

Gregory Apker[1], Christopher Buneo[1]

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1-G-84 Synaptic changes in strength at the hippocampal formation during the acquisition of classical eyeblink conditioning in behaving rabbits

Alejandro Carretero[1], Renny Pacheco[1], Jose Maria Delgado[1], Agnès Gruart[1]

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1-G-85 Correlates of desirability in the primary motor cortex of primates

Joseph Francis[1], Brandi Marsh[1], Marcello DiStasio[1], Aditya Tarigoppula[1]

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1-G-86 A context-dependent process mediates decay in motor adaptation

James Ingram[1], J Randall Flanagan[2], Daniel M Wolpert[1]

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1-G-87 Evolution of grip and object representations in the MI-PMv circuit: A neural trajectory analysis

Carlos Vargas-Irwin[1], Lachlan L Franquemont[1], Michael J Black[2], John P Donoghue[1]

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1-G-88 Trial-by-trial assessment of separate learning processes during motor adaptation

Jordan Taylor[1], Melissa A Burney[1], Jacob L Wilson[1], John W Krakauer[2], Richard B Ivry[1]

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Scholarship Winners

New investigators and faculty are essential for the future of any field of scientific inquiry. NCM has historically encouraged conference participation by graduate students and post-doctoral fellows. The scholarship program is designed to provide partial support for them to participate in the conference and is open to student and post-doc members in good standing. Our scholarship program is funded through the support of our sponsors.

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Raed Joundi	Oxford University	Dr. Ned Jenkinson
Joseph O'Doherty	University of California, San Francisco	Philip N. Sabes
David Thura	University of Montreal	Paul E. Cisek
Aaron Wong	Johns Hopkins University School of Medicine	Mark Shelhamer

Innovative Technology for High-Channel-Count Invasive and Non-Invasive Brain Mapping.

Poster Sessions | Authors, Titles and Affiliations

Session 2 Posters are listed by theme.

A - Adaptation & Plasticity in Motor Control

2-A-1 Cerebellar rTMS disrupts fast learning motor adaptation process

Robert Hardwick[1], Jon S Kennedy[1], Chris Miall[1]

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2-A-2 Transfer of motor learning between the two arms

Robert van Beers[1], Eli Brenner[1], Jeroen B Smeets[1]

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2-A-3 Sensori-motor adaptation to a novel force field does not transfer to the non-exposed arm in aged adults and a proprioceptively-deafferented patient

Fabrice Sarlegna[1], Marvin Dufrenne[2], Lionel Bringoux[2], Jean-Louis Vercher[1], Christophe Bourdin[2]

[1]CNRS & Aix-Marseille University, [2]Aix-Marseille University

2-A-4 More realignment for imposed than for naturally occurring biases

Jeroen Smeets[1], Katinka van der Kooij[1], Robert J van Beers[1], Willemijn D Schot[1], Eli Brenner[1]

[1]VU University

2-A-5 Transcranial direct-current stimulation (tDCS) over somatosensory cortex modulates synaptic mechanisms involved in classical eyeblink conditioning in rabbits

Javier Márquez-Ruiz[1], Rocío Leal-Campanario[1], Raudel Sánchez-Campusano[1], Claudia Ammann[1], Behnam Molaee-Ardekani[2], Fabrice Wendling[2], Giulio Ruffini[3], Agnès Gruart[1], José María Delgado-García[1]

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2-A-6 tDCS modulates adaptation strategies in a myoelectric-controlled interface task

Claire Schofield[1], Kianoush Nazarpour[1], Andrew Jackson[1]

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2-A-7 Modular learning of different kinematic perturbations: A model-based approach

Laura Patanè[1], Francesco Nori[1], Bastien Berret[1], Alessandra Sciutti[1], Giulio Sandini[1]

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2-A-8 Inter-manual transfer in a neuromotor interface: An age-controlled study

Sabine Gretenkord[1], Kianoush Nazarpour[1], Andrew Jackson[1], Janet Eyre[1], Sara Graziadio[1]

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2-A-9 Proprioceptive training on a desired trajectory improves motor learning

Jeremy Wong[1], Dinant A Kistemaker[1], Paul L Gribble[1]

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2-A-10 Capacity of LTP-like plasticity is essential for motor learning

Gabriela Cantarero[1], Rebecca O'Malley[1], Pablo A Celnik[1]

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2-A-11 Parietofrontal visuomotor pathway integrity after stroke determines volitional sensorimotor rhythm (SMR) modulation skill

Ethan Buch[1], Amir Modir Shanechi[2], Alissa D Fourkas[1], Cornelia Weber[3], Niels Birbaumer[3], Leonardo G Cohen[1]

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2-A-12 Can older adults learn new dynamics?

Alaa Ahmed[1], Helen J Huang[1]

[1]University of Colorado

2-A-13 The role of the cerebellum in force-field adaptation

Damien Pastor[1], Adrian Haith[2], Yves Rossetti[1], Reza Shadmehr[2], Jacinta O'Shea[3]

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2-A-14 Neurophysiological constraints for biological plausibility of machine learning

Martin Nilsson[1], Fredrik Bengtsson[2], Carl-Fredrik Ekerot[2], Henrik Jörntell[2]

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2-A-15 Dual processes in prism adaptation - Evidence from computational modelling and transcranial direct current stimulation

Jon Kennedy[1], Damien Pastor[2], Valerie Gaveau[2], Matthieu Kandel[2], Yves Rossetti[2], Chris Miall[1], Jacinta O'Shea[3]

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2-A-16 Changes of phase synchrony in motor learning during whole versus parts practice

Pablo Burgos[1]

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2-A-17 A shared mechanism underlying the use of visual and proprioceptive information in reaching and grasping

Karen Bourns[1], Francisco Colino[1], Darian Cheng[1], Keith Brewster[1], Brendan Cameron[1], Gordon Binsted[1]

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2-A-18 Changes in muscle synergies during adaptation to novel visuomotor transformations

Denise Berger[1], Reinhard Gentner[1], Timothy Edmunds[2], Dinesh K Pai[2], Andrea d'Avella[1]

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2-A-19 Bihemispheric transcranial direct current stimulation enhances skill learning and transfer to the untrained hand

Jörn Diedrichsen[1], Sheena Waters-Metenier[1], Masud Husain[1], Tobias Wiestler[1], Jörn Diedrichsen[1]

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2-A-20 Dominant arm is not always dominant: A hidden excellence of non-dominant arm in adapting to dynamical environments resulting from contralateral arm movement

Atsushi Yokoi[1], Masaya Hirashima[1], Daichi Nozaki[1]

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2-A-21 Partial learning of object dynamics based on fingertip forces in the absence of kinematic errors

Frederic Danion[1], Jonathan S Diamond[2], Randy J Flanagan[2]

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2-A-22 Cerebellar modulation of human associative plasticity

Masashi Hamada[1], Nagako Murase[1], Anna Sadnicka[1], Joseph M Galea[1], Mark J Edwards[1], John C Rothwell[1]

[1]UCL Institute of Neurology

2-A-23 Cortical plasticity in elite athletes: Lessons for brain injury rehabilitation

Damon Hoad[1], Lekshmi Desikan[1], Poppy Flanagan[1], Sam Shribman[1], Paul Hammond[1], Richard Greenwood[1], John Rothwell[1]

[1]Institute of Neurology

2-A-24 Role of reuniens-medial prefrontal cortex and reuniens-hippocampal CA1 pathways in associative learning

Juan Carlos López Ramos[1], Lyndell Eleore[1], Rafael Guerra-Narbona[1], José María Delgado-García[1]

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2-A-25 Analysis in individual differences in learning curves reveals greater variability for short time-scale motor adaptation

Yohsuke Miyamoto[1], Maurice A Smith[1]

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2-A-26 Reinforcement learning of 2-joint virtual arm reaching in motor cortex

William Lytton[1],[3], Samuel A. Neymotin[1], George L. Chadderdon[1], Cliff C. Kerr[1],[2] Joseph T. Francis[1]

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2-A-27 The influence of prior experience and symbolic cueing on human path integration

Stefan Glasauer[1],[2],[3], Paul Maier[1],[2], Frederike H. Petzschner[1],[3]

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B - Integrative Control of Movement

2-B-33 The negative BOLD homunculus: Different contributions of negative and positive BOLD to the somatotopic representation in motor homunculi in humans

Noa Zeharia[1], Tamar Flash[2], Amir Amedi[1]

[1]Hebrew University of Jerusalem, [2]Weizmann Institute of Science

2-B-34 Eye movement characteristics during ball catching

Benedetta Cesqui[1], Francesco Lacquaniti[1], Andrea d'Avella[1]

[1]IRCSS Santa Lucia Fundation

2-B-35 Rapid updating of the time-course of the visuomotor reflex gain to task demands

Michael Dimitriou[1], David W Franklin[1], Daniel M Wolpert[1]

[1]University of Cambridge

2-B-36 Nonlinear interactions between visuomotor responses to hand and target motion: Evidence against the difference vector model

Sae Franklin[1], Alexandra Reichenbach[2], Jörn Diedrichsen[2], David W Franklin[1]

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

2-B-37 Cortical activity differentiates automatic and controlled processes in a speeded response switching task

Douglas Cheyne[1], Paul Ferrari[1], James A Cheyne[2]

[1]Hospital for Sick Children, [2]University of Waterloo

2-B-38 Spatiotemporal characteristics of muscle patterns during ball catching

Mattia D' Andola[1], Benedetta Cesqui[1], Alessandro Portone[1], Francesco Lacquaniti[1], Andrea d'Avella[1]

[1]Santa Lucia Foundation

2-B-39 Catching something we don't see. How can that be done?

Gianfranco Bosco[1], Delle Monache[2], Francesco Lacquaniti[2]

[1]University of Rome Tor Vergata, [2]University of Rome Tor Vergata / IRCCS Santa Lucia Foundation

2-B-40 A model of visuomotor coordination and submovements in three dimensional object interception

Sang Hoon Yeo[1], Martin Lesmana[1], Debanga R Neog[1], Dinesh K Pai[1]

[1]University of British Columbia

2-B-41 Firing pattern of spinal interneurons mediating a variety of segmental reflex pathway in awake, behaving monkey : A new hypothesis

GeeHee Kim[1], Tomohiko Takei[1], Kazuhiko Seki[1]

[1]National institute of Neuroscience

2-B-42 Analysis of spinal interneuron circuitry in low-level motor control of cat forepaw

Henrik Jörntell[1], Fredrik Bengtsson[1], Pontus Geborek[1], Anton Spanne[1]

[1]Lund University

2-B-43 Agency assignment for automatic responses in reaching movements

Alexandra Reichenbach[1], David W Franklin[2], Jörn Diedrichsen[1]

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

2-B-44 Cervical kinematics and neuromuscular activity of whiplash patients in the early stage and 6 months after trauma

Pierre-Paul Vidal[1], Jennyfer Lecompte[1], Baptiste Sandoz[2], Sophie Bancho[3], Danping Wang[1], Sebastien Laporte[2]

[1]CNRS, [2]Arts et Metiers ParisTech, [3]Institut pour la Recherche sur la Moelle épinière et l'Encéphale

2-B-45 Why does picture naming take longer than word reading? Contribution of motor processes

Nicole Malfait[1], Stéphanie Ries[2], Thierry Legou[1], Boris Burle[1], F.-Xavier Alario[1]

[1]CNRS & Aix-Marseille Université, [2]University of California at Berkeley, [3]

2-B-46 Training at different movement speeds: Transfer to different speeds or directions of movement

Ulrike Hammerbeck[1], Nada Yousif[2], Joern Diedrichsen[2], John C Rothwell[1]

[1]Institute of Neurology, UCL, [2]Institute of Cognitive Neuroscience, UCL

2-B-47 Role of the rostral medial prefrontal cortex during the associative learning in behaving rabbits

Rocio Leal Campanario[1], José María Delgado García[1], Agnès Gruart[1]

[1]Pablo de Olavide University

2-B-48 Anosmin-1-over-expression on in vivo hippocampal long-term potentiation and postnatal neurogenesis

V. Murcia-Belmonte[1], D. García-González[1], P.F. Esteban[1], A. Gruart[2], J.M. Delgado-García[2], F. de Castro[1]

[1]Grupo de Neurobiología del Desarrollo-GNDe, Hospital Nacional de Parapléjicos, [2]Division of Neurosciences, Pablo de Olavide University

D - Disorders of Motor Control

2-D-81 Clinical assessment tool development: Measuring cognitive-motor integration in healthy aging and early Alzheimer's disease

Kara Hawkins[1], Jeya Thayaparan[2], Adriana Bida[3], Lauren E Sergio[1]

[1]York University, [2]York Central Hospital, [3]Southlake Regional Health Centre

2-D-82 Progressive resistance exercise improves bradykinesia and muscle activation patterns in parkinson's disease

Fabian David[1], Julie A Robichaud[1], Sue E Leurgans[2], David E Vaillancourt[3], Cynthia Poon[1], Wendy M Kohrt[4], Cynthia L Comella[2], Daniel M Corcos[1]

[1]Universtiy of Illinois at Chicago, [2]Rush University Medical Center, [3]University of Florida, [4]University of Colorado School of Medicine

2-D-83 Nonlinear summation of evoked forces and EMG using intraspinal microstimulation trains in the macaque monkey

Jonas Zimmermann[1], Andrew Jackson[1]

[1]Newcastle University

2-D-84 Sham-controlled study of transcranial direct current stimulation (TDCS) for dystonia in children

Scott Young[1], Matteo Bertucco[1], Terence D Sanger[1]

[1]University of Southern California

2-D-85 Vibro-tactile biofeedback for neuromuscular rehabilitation in children with dystonia

Francesca Lunardini[1], Serena Maggioni[1], Claudia Casellato[1], Matteo Bertucco[2], Alessandra Laura Giulia Pedrocchi[1], Terence D Sanger[2]

[1]Politecnico di Milano, [2]University of Southern California

2-D-86 Kinematics analysis of constrained reaching movements in children with dystonia

Matteo Bertucco[1], An Chu[1], Terence D Sanger[1]

[1]University of Southern California

2-D-87 Development of a new brain ischemia model to induce motor deficit in the non-human primate: Anterior choroidal artery occlusion

Sandra Milena Puentes Martinez[1], Kazuhiko Seki[1]

[1]National Institute of Neurosciences

2-D-88 Spasticity emerges when abnormal firing thresholds are introduced into the spine neuronal network emulated on hardware

C. Minos Niu[1], Sirish K Nandyala[1], Won Joon Sohn[1], Terence D Sanger[1]

[1]University of Southern California

2-D-89 Kinematic investigations of reaching slowness in hemiparetic stroke patients

Agnes Roby-Brami[1], Laurence Mandon[2], Johanna V Robertson[2], Raphael Zory[2], Djamel Bensmail[2]

[1]University Pierre et Marie Curie, CNRS, [2]Hôpital Raymond Poincaré

2-D-90 Quantitative assessment of driving performance in Parkinsons disease (PD): Deficient coordination of gaze-hand-feet-control with a deactivated sub-thalamic nucleus stimulator

Wolfgang H. Zangemeister[1], Lea Maintz[1], Carsten Buhmann[1]

[1]Universität Hamburg

2-D-91 Decreased saccade velocity in spinocerebellar ataxia 6

John Anderson[1], Peka C Savayan[2]

[1]University of Minnesota, [2]Minneapolis VA Health Care System

2-D-92 Developmental dyspraxia in children with motor disorders

Stefanie Bodison[1], Terence Sanger[1]

[1]University of Southern California

F - Fundamentals of Motor Control

2-F-28 Investigating motor learning with the ETH Pattus - a robotic approach to studying the neural control of forelimb movements in rodents

Bogdan Vigaru[1], Olivier Lambercy[1], Maximilian Schubring-Giese[2], Jonas Hosp[2], Melanie Schneider[1], Andreas Luft[2] , Roger Gassert[1]

[1]ETH Zurich, [2]University of Zurich

2-F-29 Mental rotation of hand movements in congenitally blind subjects

Maitê Mello Russo[1], Luis Aureliano Imbiriba[2], Laura Alice Santos de Oliveira[1], Erika de Carvalho Rodrigues[3], Claudia Domingues Vargas[1]

[1]IBCCF/UFR, [2]EEFD/UFRJ, [3]UNISUAM

2-F-30 Muscle specific modulation of corticospinal excitability depends on valence of the object to be grasped

Anaelli Aparecida Nogueira-Campos[1], Laura Alice Santos de Oliveira[1], Valeria Della-Maggiore[1], Paula de Oliveira Esteves[1], Érika de Carvalho Rodrigues[2], Cláudia Domingues Vargas[1]

[1]Instituto de Biofísica Carlos Chagas Filho / UFRJ, [2]UNISUAM

2-F-31 Directional tuning of arm muscle activation in isometric force generation and its prediction by flexible and synergistic models

Daniele Borzelli[1], Andrea D'Avella[1], Reinhard Gentner[1], Timothy Edmunds[2], Dinesh K Pai[2]

[1]Santa Lucia Foundation, [2]University of British Columbia

2-F-32 Context dependent changes in cue responses prior to movement in primate ventral premotor cortex

Lachlan L. Franquemont[1], Carlos E Vargas-Irwin[1], Michael J Black[2], John P Donoghue[1]

[1]Brown University, [2]Max Plank Institute for Intelligent Systems

2-F-49 Reach and grasp encoding in macaque parietal area AIP

Hans Scherberger[1], Sebastian J Lehmann[1]

[1]German Primate Center

2-F-50 Role of motor cortex in skill learning depends on learning strategy

Risa Kawai[1], Tim Markman, Bence P Ölveczky[1]

[1]Harvard University

2-F-51 The influence of movement speed on variances of target tracking arm movements using a computer mouse

Jozsef Laczko[1], Bence Borbely[2], Gabor Fazekas[3], Jozsef Takacs[2]

[1]Pazmany Peter Catholic University and Semmelweis University, [2]Pazmany Peter Catholic University, [3]National Institute for Medical Rehabilitation

2-F-52 How octopuses coordinate their eight flexible arms while crawling

Guy Levy[1], Tamar Flash[2], Benny Hochner[1]

[1]Hebrew University of Jerusalem, [2]Weizmann Institute of Science

2-F-53 Functional characterization of the cholinergic motor innervation in the special neuromuscular system of the octopus arm

Nir Nesher[1], Naomi Feinstein[1], Lili Englister[1], Finkel Eran[1], Benny Hochner[1]

[1]Hebrew University of Jerusalem

2-F-54 When emulation becomes reciprocity

Luisa Sartori[1]

[1]Università degli studi di Padova

2-F-55 Hierarchical representations of object manipulation tasks

Anastasia Sylaidi[1], Aldo Faisal[1]

[1]Imperial College London

2-F-56 Expectation about movement error and its influence on real-time reach control

Darian Cheng[1], Brendan Cameron[1], Gordon Binsted[1]

[1]University of British Columbia

2-F-57 Thalamo-cortical network in locomotion

Irina Beloozerova[1], Vladimir Marlinski[1], Mikhail G Sirota[1]

[1]Barrow Neurological Institute

2-F-58 Limb movement amplitude systematically influences temporal order judgments

Robert Hermosillo[1], Paul van Donkelaar[1]

[1]University of British Columbia - Okanagan

2-F-59 Properties of force fields in the primate arm induced by intraspinal microstimulation

Hiroaki Yaguchi[1], David P Kowalski[2], Tomohiko Takei[1], Kazuhiko Seki[1]

[1]National Institute of Neuroscience, [2]Drexel University

2-F-60 Evidence for distinct posture and movement states at the neural population level

Nicholas Sachs[1], Christian Ethier[1], Rachel M Cassidy[1], David P Bontrager[1], Zachary A Wright[1], Lee E Miller[1]

[1]Northwestern University

2-F-61 Dissociating anticipatory control of digit positions and force in the primary motor cortex

Marco Davare[1], Qiushi Fu[2], Jason Choi[2], Marco Santello[2]

[1]Institute of Neurology, [2]Arizona State University

2-F-62 Development of spatial and temporal bimanual coordination during childhood

Betteco de Boer[1], Lieke Peper[1], Peter J Beek[1]

[1]VU University

2-F-63 Neuronal correlates of running speed in the dorsal striatum

Pavel Rueda-Orozco[1], David Robbe[1]

[1]Institut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS) (NIF:Q5856414G)

G - Theoretical & Computational Motor Control

2-G-64 Gravity-compensating muscular torque explains biases in perceived arm-movement extent

Nienke Debats[1], Jeroen Smeets[1], Robert J van Beers[1]

[1]VU University Amsterdam

2-G-65 Algorithms for shaping the dynamics of a bidirectional neural interface

Marianna Semprini[1], François D Szymanski[1], Francesco Grussu[2], Ferdinando A Mussa-Ivaldi[3], Stefano Panzeri[1], Alessandro Vato[1]

[1]Istituto Italiano di Tecnologia, [2]University of Genoa, [3]Northwestern University

2-G-66 Transitions between rhythmic and discrete performance in unimanual movements

Hamal Marino[1], Neville Hogan[2], Marcos Duarte[3], Steven Charles[4], Lauren DiPietro[2], Dagmar Sternad[5]

[1]Scuola Superiore Sant'Anna, [2]Massachusetts Institute of Technology, [3]University of Sao Paulo, [4]Brigham Young University, [5]Northeastern University

2-G-67 Modeling gaze-dependent errors when reaching to visual and proprioceptive targets

Joost Dessing[1], Masahiro Kokubu[1], Armin Abadeh[1], Patrick A Byrne[1], J. Douglas Crawford[1]

[1]York University

2-G-68 Behavioral insights into neural mechanisms of movement planning: Continuous and abrupt updating of a motor plan following changes in task goals

David Huberdeau[1], Adrian M Haith[1], John Krakauer[1]

[1]Johns Hopkins University

2-G-69 Heterogeneous attractor modules for motor planning in macaque premotor cortex

Maurizio Mattia[1], Stefano Ferraina[2], Pierpaolo Pani[2], Giovanni Mirabella[2], Stefania Costa[2], Paolo Del Giudice[1]

[1]Istituto Superiore di Sanità, [2]Sapienza University

2-G-70 The traveling salesman problem in human motor tasks

Jakob Uecker[1], Aldo Faisal[1]

[1]Imperial College London

2-G-71 Towards the metabolic basis of the cost function in human motor control

Scott Taylor[1], Aldo A Faisal[1]

[1]Imperial College London

2-G-72 Mechanisms for variability estimation in the motor system

Maurice Smith[1], Alkis Hadjiosif[1]

[1]Harvard University

2-G-73 Tapping along with ADAM: Synchronizing with an adaptive and anticipatory virtual partner

Maria C van der Steen[1], Merle T Fairhurst[1], Peter E Keller[1]

[1]Max Planck Institute for Human Cognitive and Brain Sciences

2-G-74 Coordinate dependence and distribution dependence of blind source separation for motor synergies: Robust separation behavior of ICA across transforms.

Corey Hart[1], Simon Giszter[1]

[1]Drexel University College of Medicine

2-G-75 Influence of arm velocity on haptic localization

Femke Maij[1], W. Pieter Medendorp[2], Alan M Wing[1]

[1]University of Birmingham, [2]Donders Institue for Brain, Cognition and Behaviour, Radboud University Nijmegen

2-G-76 Co-articulate of straight movements with an artificial neural network

Andre Lemme[1], Yaron Meirovitch[2], Tamar Flash[2], Jochen Steil[1]

[1]Research Institute for Cognition and Robotics, [2]Weizmann Institute of Science

2-G-77 Task-dependent structure of neuronal variability during abstract BMI control

Kianoush Nazarpour[1], Tom M Hall[1], Andrew Jackson[1]

[1]Newcastle University

2-G-78 A common motor optimisation principle in healthy subjects and parkinsonian patients

Pierre Baraduc[1], Stéphane Thobois[2], Jing Gan[2], Emmanuel Broussolle[2], Michel Desmurget[1]

[1]CNRS / U. Lyon, [2]Lyon Pierre Wertheimer Neurological Hospital

2-G-79 Arm-EMG control for assistive lower limb exoskeleton

Francesca Sylos Labini[1], V La Scaleia[1], M J MacLellan[1], T Hoellinger[2], K Seetharaman[2], M Petieau[2], A Bengoetxea[2], G Cheron[2], Y P Ivanenko[1]

[1]Santa Lucia Foundation, [2]Université libre de Bruxelles

2-G-80 Automatic synthesis of complex behaviors with optimal control

Emo Todorov[1], Igor Mordatch[1], Yuval Tassa[1], Tom Erez[1], Zoran Popovic[1]

[1]Computer Science and Engineering, University of Washington

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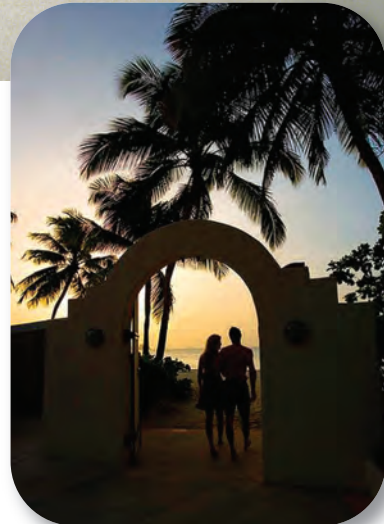
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Poster Session Floor Plans Venetian Ballroom A & B & Foyer

Foyer

Entrance

Exhibit Tables

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105	90
104	91
103	92
102	93

Coffee

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Foyer

Food

To Foyer

Venetian Ballroom
A & B

1 2 3 4 5 6 7 8 9 10 11   12 13 14 15 16 17 18 19 20 21 22

44 43 42 41 40 39 38 37 36 35 34   33 32 31 30 29 28 27 26 25 24 23

45 46 47 48 49 50 51 52 53 54 55   56 57 58 59 60 61 62 63 64 65 66

88 87 86 85 84 83 82 81 80 79 78   77 76 75 74 73 72 71 70 69 68 67

Food

Food

Venetian Ballroom C, D & E   All meeting sessions will be held here.

Poster Layout
Session 1
Tuesday, April 24 & Wednesday, April 25
Venetian Ballroom A & B and Foyer

THEMES

- ☐ A - Adaptation & Plasticity in Motor Control
- ☐ B - Integrative Control of Movement
- ☐ C - Control of Eye & Head Movement
- ☐ D - Disorders of Motor Control
- ☐ E - Posture & Gait
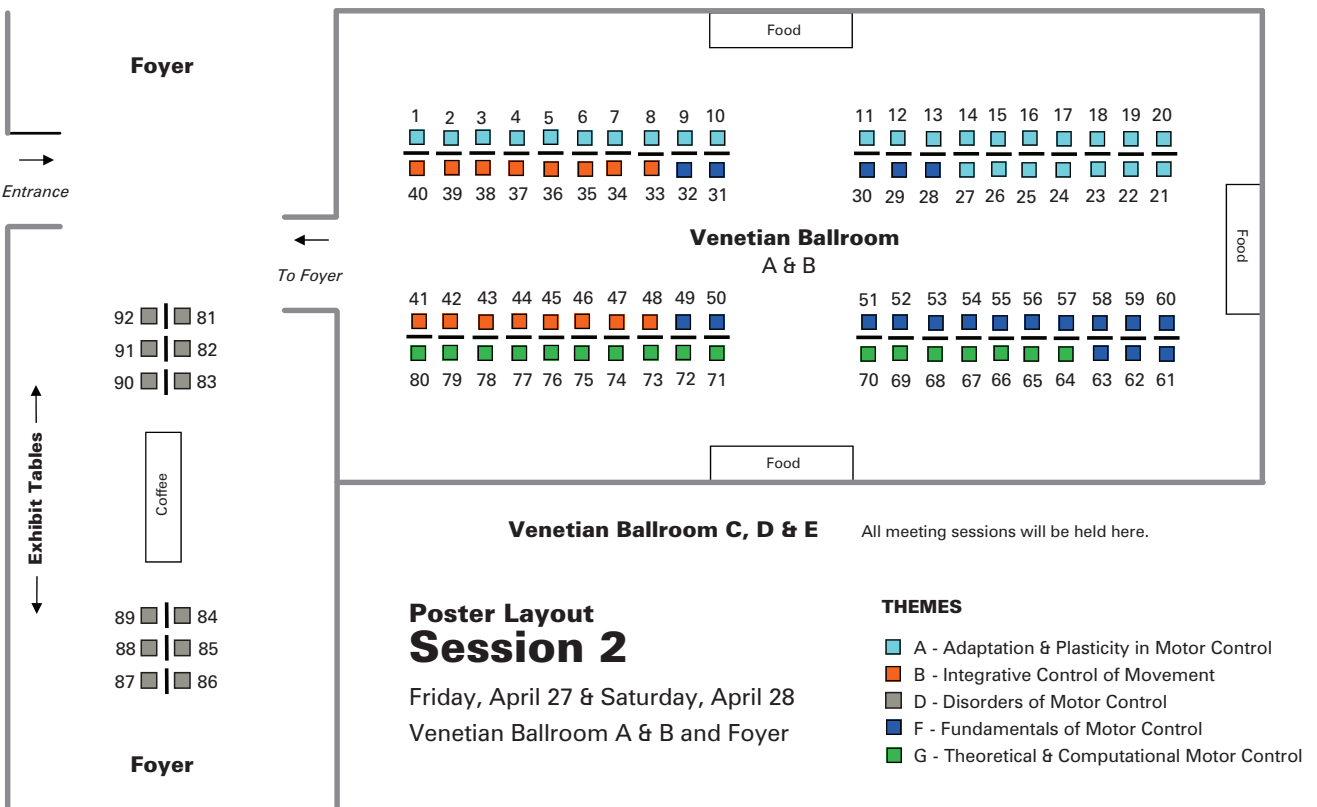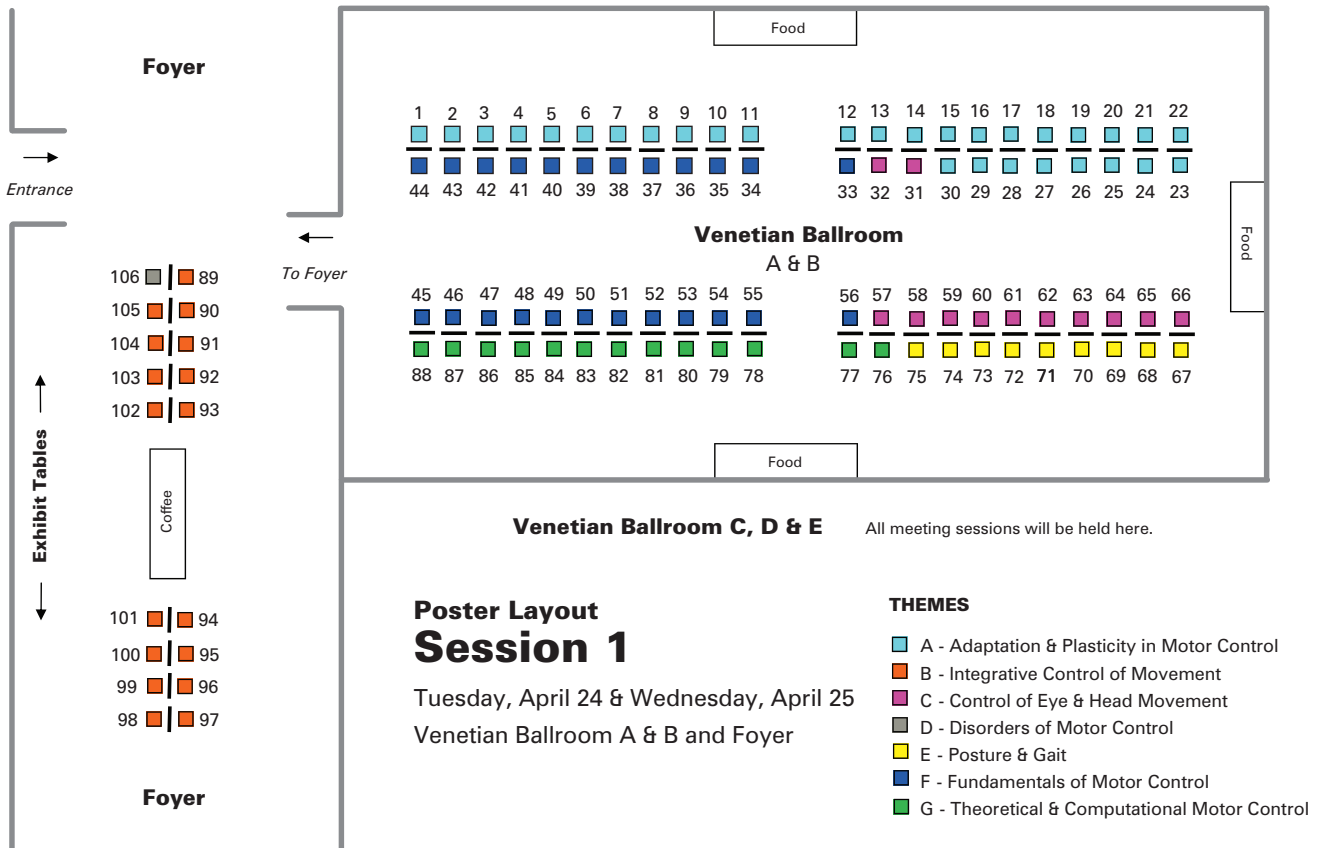- ☐ F - Fundamentals of Motor Control
- ☐ G - Theoretical & Computational Motor Control

Foyer

Entrance

Exhibit Tables

92	81
91	82
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Coffee

89	84
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Foyer

Food

To Foyer

Venetian Ballroom
A & B

1 2 3 4 5 6 7 8 9 10   11 12 13 14 15 16 17 18 19 20

40 39 38 37 36 35 34 33 32 31   30 29 28 27 26 25 24 23 22 21

41 42 43 44 45 46 47 48 49 50   51 52 53 54 55 56 57 58 59 60

80 79 78 77 76 75 74 73 72 71   70 69 68 67 66 65 64 63 62 61

Food

Food

Venetian Ballroom C, D & E   All meeting sessions will be held here.

Poster Layout
Session 2
Friday, April 27 & Saturday, April 28
Venetian Ballroom A & B and Foyer

THEMES

- ☐ A - Adaptation & Plasticity in Motor Control
- ☐ B - Integrative Control of Movement
- ☐ D - Disorders of Motor Control
- ☐ F - Fundamentals of Motor Control
- ☐ G - Theoretical & Computational Motor Control

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