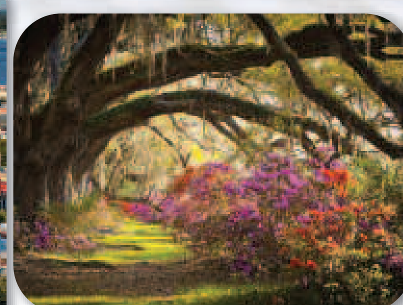
Society for the
Neural Control of Movement
NCM

25TH NCM Annual Meeting





Satellite Meeting
April 20, 2015

25th Annual Meeting
April 21 – 24, 2015

Francis Marion Hotel

Charleston **South Carolina**

2015 At-A-Glance Satellite and Annual Conference Schedule

Charleston, South Carolina

Society for the **Neural Control of Movement**

NCM

Satellite Meeting April 19 – 20, 2015

25th AnnualMeeting April 21 – 24, 2015

Schedule subject to change without notice.

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

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr
Arrivals, Free Time	**Registration /Information Desk Open**	**Registration / Information Desk Open**	**Registration / Information Desk Open**	**Registration / Information Desk Open**	**Registration / Information Desk Open**	**Free / Travel time**
Satellite Registration	**Satellite Meeting Coffee Service** (08:00 - 08:30)	**Posters on Display (Session 1)**	**Posters on Display (Session 1)**	**Posters on Display (Session 2)**	**Posters on Display (Session 2)**	
Satellite Registration Upper Lobby (17:00 - 19:00)	**Satellite Meeting Session 1:** Harnessing sensory and motor experience induced plasticity following injury (08:30 - 10:30)	**Exhibits on Display**	**Exhibits on Display**	**Exhibits on Display**	***Session 12*** **Panel VI** **Wolpaw** (08:00 - 10:15)	
Satellite Drinks Reception Lobby Bar (18:00 - 19:00)	**Break** (10:30 - 11:00)	***Session 1*** **Panel I** **Mendendorp** (08:00 - 10:15)	***Session 5*** **Panel III** **Sternad** (08:00 - 10:15)	***Session 9*** **Individual Presentations II** (08:00 - 9:40)	**Break** (10:15 - 10:45)	
	Satellite Meeting Session 2: Brain stimulation to enhance plasticity and motor recovery (11:00 - 13:00)	**Break** (10:15 - 10:45)	**Break** (10:15 - 10:45)	**Break** (9:40 - 10:10)	***Session 13*** **Individual Presentations III** (10:45 - 12:45)	
	Lunch **(13:00 - 14:00)** **Satellite Meeting Poster Session** **(13:00 - 15:30)**	***Session 2*** **Panell II** **Ahmed** (10:45 - 13:00)	***Session 6*** **Panel IV** **Grafton** (10:45 - 13:00)	***Session 10*** **Perspective I** **Bensmaia** (10:10 - 11:40)	***Session 14*** **Poster 2b** **Lunch** (12:45 - 14:45)	
	Satellite Meeting Session 3: Personalization of rehabilitation based on an individual's underlying pathophysiology (15:30 - 17:30)	***Session 3*** **Poster 1a** **Lunch** (13:00 - 15:00)	***Session 7*** **Poster 1b** **Lunch** (13:00 - 15:00)	**Members Meeting** (11:40 - 12:10)	***Session 15*** **Perspective II** **Gizster** (14:45 - 16:15)	
	Satellite Meeting Session 4: Wrap Up (17:30 - 18:00)	***Session 4*** **Individual Presentations I** (15:00 - 17:00)	***Session 8*** **Panel V** **Seidler** (15:00 - 17:00)	***Session 11*** **Poster 2a** **Lunch** (12:10 - 14:10)	***Session 16*** **Keynote Speaker** **Peter Strick** (16:15 - 17:30)	
	Registration (17:00 - 19:00)	**Free Time**	**Free Time**	**Free Time and/or Excursions**	**Closing Drinks Reception** Lobby Bar (17:30 - 18:30)	
	Conference Registration Upper Lobby (18:00 - 19:30)				**Free Time**	
	Opening Reception **Vincent Chicco's Restaurant** (off site) (19:00 - 21:00)					

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 250, 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 typically in April every year.

Welcome

To the Society for the Neural Control of Movement 25th Annual Meeting

Gary Paige, President

Welcome to our 25th Annual Conference in Charleston, South Carolina. At this time it is fitting to provide some comments about NCM, the meeting, and its venue. First, the Society remains both healthy and vibrant. NCM has witnessed continued engagement and attendance even through the challenging years of international recession. The upcoming conference sits well in a line of exciting meetings in novel locations, while our tradition of dynamic programming tracks our membership and our shifting interests. NCM continues to attract new and established investigators, from senior faculty ranks to students, and across a uniquely broad blend of disciplines that in turn infuses our various presentation formats, all matched by a mix of vibrancy, diversity, informality and collegiality. Thanks are due to all within the NCM community.

Second, NCM will continue to succeed only in light of programmatic novelty, which ultimately means new members and contributors that stem from young investigators and novel collaborations. Over half of our meeting attendance now constitutes students and post-docs, a proportion that has continued to rise. Further, our scholarship program has grown since the early years, thanks to the remarkable efforts of Lee Miller, our Development Officer. Awards continue to be scattered across North America and abroad alike. The program serves to encourage, and incentivize, participation by students and post-docs within NCM sessions and presentations.

Third, we continue to hone our annual meetings through 'experiments'. These include identifying new meeting sites, including Charleston this year, reflecting yet another example of diversity of venues. Opportunity, meeting costs, ecology, and conveniences (scientific and social) are all attributes that enter the equation for a successful and exciting meeting. Our next experiments will follow the trend—innovative scientific programs with similarly exciting locations for attendees and their families to enjoy. For next year Marischal De Armond and I have secured a remarkable opportunity in the Caribbean, to be followed by a return to Europe the following year. I look forward to presenting more at the upcoming 'members meeting,' so please attend.

Fourth, experiments in meeting structure continue. Doug Munoz, our VP and Program Chair, has once again organized a magnificent program. We continue our successful and popular tradition of holding a grazing lunch during afternoon poster sessions (two days for each of two sets of posters) while also providing time to visit our increasing number of sponsor exhibits. This structure engages attendees intensely throughout the day, ending earlier on some days to allow time with friends, family, and colleagues into the evening. In addition, this year's meeting follows a recent tradition of including a 1-day satellite on the day preceding the main meeting, here organized by Steve Kautz, on the topic of neuro-rehabilitation. I and the Board (identifiable by our badges) solicit your feedback on all of the above and including the meeting's content.

Fifth, NCM continues to reap substantial benefits through our collaboration with Podium Conference Specialists. The guidance and support they provide for our Society's affairs and for the planning and management of our Conferences allow us to enhance the offerings and service to all members. Marischal, Laurie and Darcy remain available to you throughout the conference to help with any questions or support you need to ensure a high-quality experience during the meeting.

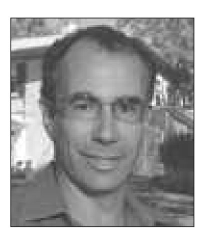
Finally, I, my fellow Officers, and the NCM Board welcome all to a truly outstanding conference in Charleston.

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

Steve Scott

Lee Miller

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
Steve Scott (treasurer@ncm-society.org)

Development Officer
Lee Miller (sponsor@ncm-society.org)

Board Members

Name	Institution	Country	Term
Andrea d'Avella[2]	Santa Lucia Foundation	Italy	2012 – 2015
John van Opstal[1]	Donders Institute	Netherlands	2013 – 2016
Rachel Seidler[1]	University of Michigan	USA	2013 – 2016
Jorn Diedrichsen[1]	University College London	England	2014 – 2017
Chris Miall[2]	University of Birmingham	UK	2012 – 2015
Andrew Pruszynski[1]	Umea University	Sweden	2012 – 2015
Daichi Nozaki[1]	University of Tokyo	Japan	2012 – 2015
Lena Ting[1]	Emroy University	USA	2013 – 2016
Brian Corneil[1]	University of Western Ontario	Canada	2013 – 2016
Jeroen Smeets[1]	VU University Amsterdam	Netherlands	2011 - 2014
Kathleen Cullen[2]	McGill University	Canada	2014 – 2017
Jean-Jacques Orban de Xivry[1]	Catholic University of Louvain	Belgium	2014 – 2017

Incoming Board Members
The following members will begin their term at the 2015 Annual Meeting:

Name	Institution	Country	Term
Scott Grafton	University of California, Santa Barbara	USA	2015 – 2018
Andrew Pruszynski	Western University	Canada	2015 – 2018
Alaa A. Ahmed	University of Colorado	USA	2015 – 2018
Dagmar Sternad	Northeastern University	USA	2015 - 2018

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

Board Service

Nominations for NCM Board service open in January. 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 the NCM's Board members or Officers, or send an email to Tresurer@NCM-Society.org.

NCM Administration

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

Podium Conference Specialists
Darcy Lipsey
Jude Ross
Laurie De Armond
Marischal De Armond

NCM Membership

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 benefits include:

- Opportunity to submit proposals and abstracts for sessions at the Annual Conference
- Opportunity to submit proposals for satellite meetings
- Opportunity to register for Annual NCM Conferences 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 Conference 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.

2016 Annual Meeting

Rose Hall Resort & Spa
Montego Bay, Jamaica

We are pleased to announce the 2016 Annual Meeting will take place in the Caribbean paradise of Montego Bay, Jamaica. The Annual Meeting will take place **April 24 – 29, 2016** at the **Hilton Rose Hall Resort & Spa**. Please plan to attend the 26th Annual Meeting on the tropical shores of Montego Bay.

Nestled between the scenic mountains and turquoise Caribbean waters of Jamaica, the all-inclusive Hilton Rose Hall Resort & Spa truly inhabits an exclusive ocean-front location on the edge of Montego Bay. Set on the legendary 18th-century Rose Hall Plantation, this resort evokes the colorful charm and hospitality made famous by the island. As an all-inclusive property, the resort affords guests an increased level of comfort and convenience. Enjoy a wide array of food and beverage options. Select from an assortment of distinctive amenities and endless recreation located onsite.

Indulge in this alluring oasis and plan to attend NCM 2016, this will be one you don't want to miss. Information about the meeting 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).

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

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

Since 1991 NCM's annual conferences 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
24th Annual Meeting*	April 21 – 25, 2014	Amsterdam	Netherlands	Grand Hotel Krasnapolsky
23rd Annual Meeting*	April 16 – 20, 2013	San Juan, Puerto Rico	USA	El San Juan Hotel & Casino
22nd Annual Meeting*	April 23 – 28, 2012	Venice	Italy	Hilton Molino Stucky
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

General Meeting Information

Meeting Venue

Francis Marion Hotel
387 King Street, Charleston, South Carolina

Check in: 4:00 PM   Check out: 12:00 PM

All conference sessions will take place in this location.

The Opening Reception will be off-site at
Vincent Chicco's Restaurant
39-G John St. Charelston (Directions on page 8)

Satellite Meeting
Satellite Meeting registration fees include a complimentary drink and appetizers during a drop in gathering on Sunday April 20, access to the full day meeting with refreshment breaks, and a buffet lunch.

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, the Opening Reception, and the Closing Drinks Reception.

Additional Tickets
Tickets can be purchased separately for your guests and/or children for the Opening Reception, Closing Drinks Reception and Buffet Lunches. These additional tickets can 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, reception and banquet. 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.

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

Registration and Information Desk Hours
The NCM Registration and Information Desk, located outside the Carolina Ballroom, will be open during the following dates and times:

Sunday, April 19	17:00 – 19:00
Monday, April 20	08:00 – 15:00 and 17:00 – 19:00
Tuesday, April 21	08:00 – 15:00
Wednesday, April 23	08:00 – 15:00
Thursday, April 24	08:00 – 14:30
Friday, April 25	08:00 – 15:30

If you need assistance during the conference, 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 conference participants.

Poster Information

Set-Up / Removal: Satellite Meeting
Satellite Meeting poster presenters must set-up and remove their Satellite Meeting posters during the following times:

SET-UP: Monday, April 20 at 10:30

REMOVE: Monday, April 20 at 17:30

Set-Up / Removal: Annual Meeting
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.

Poster Session 1

SET-UP: Tuesday, April 21, 07:00 and 10:00

REMOVE: Wednesday, April 22, between 17:30 and 18:00

Poster Session 2

SET-UP: Thursday, April 23, between 07:00 and 9:30

REMOVE: Friday, April 24. Please take your poster at the end of Poster Session 2 at 14:45.

Information on Poster Authors (Lead), Poster Numbers and Poster Titles begins on page 28. For a complete copy of all the poster abstracts, a limited supply of printed abstract booklets are 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 Podium Conference Specialists can be identified by ribbons on their name badges. Feel free to ask anyone of our staff for assistance. For immediate assistance please visit us at the Registration Desk.

Business Lounge
There will be soft seating available in the Upper Lobby daily, Monday to Friday, for your convenience and comfort. NCM guests are invited to use this area for your business needs and for informal discussions and meetings.

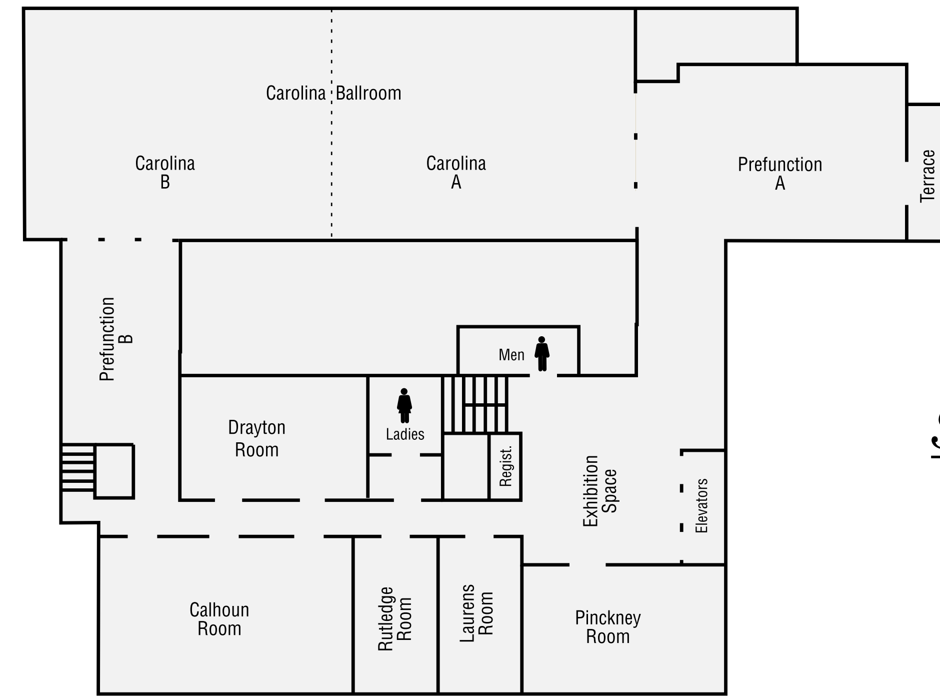
Meeting Space High-speed Internet Services

Wireless internet access is complimentary in the guest rooms, lobby and Swamp Fox Restaurant.

Wireless meeting room internet signal is named **Francis Marion Meeting**. Guest room signal is named **Francis Marion WiFi**. Users must accept terms of use on the Francis Marion splash page when logging on.

No Smoking Policy
The Francis Marion Hotel is a completely non-smoking facility.

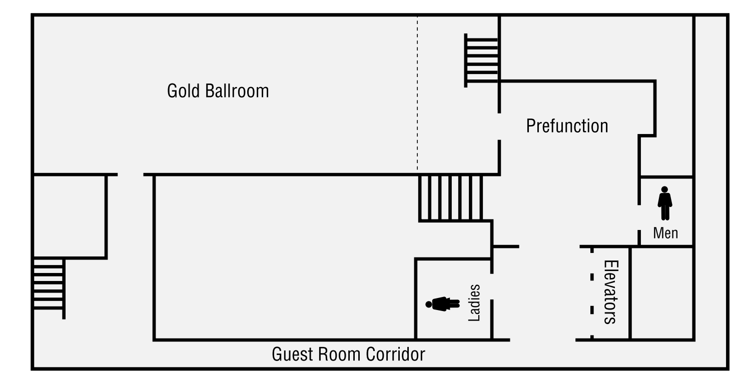
Meeting Venue Floor Plan



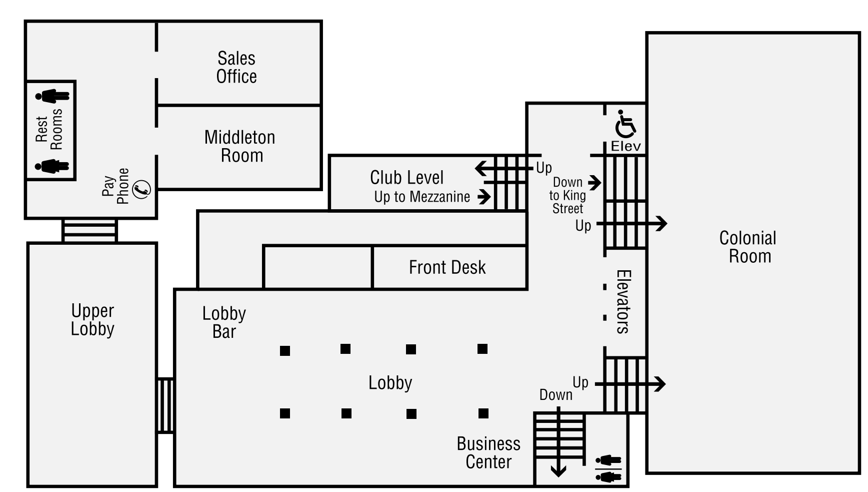
Mezzanine/Meeting Level

FRANCIS MARION
HOTEL

CHARLESTON, SC



Gold Ballroom, 2nd Floor



Colonial Room/Lobby Level

Special Meetings & Events

Sunday, April 19
18:00 – 19:00
Satellite Drinks Reception
(Satellite Meeting Registrants Only)
Francis Marion Hotel Lobby Bar

Monday, April 20
19:00 – 21:00
Opening Reception
Vincent Chicco's Restaurant
39-G John St. Charelston, SC 29403
(one complimentary drink, cash bar, hors d'oeuvres)

Directions: [Map at right] From the Francis Marion Hotel, head northwest on King Street toward Vanderhorst Street and continue on until John Street. Turn right on John Street and Vincent Chicco's will be on the right at 39-G John Street.

Thursday, April 23
11:40 – 12:10
NCM Members Meeting
Colonial Room

Friday, April 24
17:30 – 18:30
Closing Drinks Reception
(one complimentary drink, cash bar Francis Marion Hotel Lobby Bar)

Download the official NCM Mobile App!

Building on the well-received first edition of our app, we are excited to bring you the 2015 edition of the official NCM Mobile Meeting App! The app is, once again, available as a free download for iPhone, Android, Blackberry and all tablets, and in a web version for all other web browser-enabled smartphones.

Maximize your time and experience with the NCM Meeting – scan the QR code to access the app.

The NCM app allows you to:

- View all conference information (sessions, abstracts, speakers, exhibitors, maps, attendee profiles, etc.) on your mobile device
- Build a personalized schedule and access any session handouts
- Find information quickly with the search feature
- Opt into messaging with other attendees
- Receive important conference-related notifications and updates
- Take notes on your mobile device during specific sessions with the ability to extract the information later
- Browse local restaurants and attractions

And much more…

Did you access our app at the 2014 meeting in Amsterdam? If so, simply open the Podium App and select the 25th Annual Meeting App.

Conference Excursions

NCM invites you to take advantage of your visit to Charleston by exploring this wonderful city and its surroundings!

NCM has organized several excursions on **Thursday, April 23** that are custom designed to fit with the meeting's afternoon off. An overview of these options can be found below. If you are interested in joining one of these trips, please inquire at the Registration Desk located in the Upper Lobby.

Walking Tour of Charleston

3:30 – 5:30 PM, $25 per person

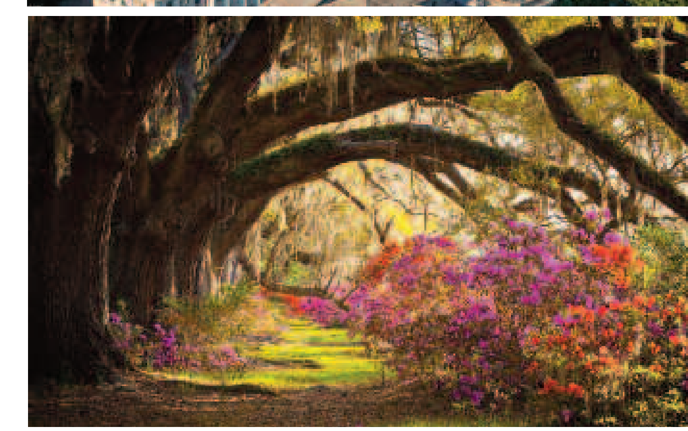
Meander through back alleyways and cobblestone streets, and stroll along the prestigious Battery, reveling in the city of Charleston's amazing beauty and historic traditions. Visit the city's most historic sites including churches, the waterfront, battle monuments, and mansions, and take in the spring gardens during the most beautiful time of year.

Magnolia Gardens Plantation

3:15 – 7:15 PM, $39 per person

Founded in 1676 by the Drayton family, Magnolia Plantation has survived three centuries and witnessed the history of the nation unfold before it from the American Revolution through the Civil War and beyond. It is the oldest public tourist site in the Lowcountry, and the oldest public gardens in America, opening its doors to visitors in 1870 to view the thousands of beautiful flowers and plants in its famous gardens.

This excursion includes transportation to/from the gardens (30 minutes outside the city), as well as admission, which grants access to the orientation theatre and gift shop. Those who wish to purchase a house tour may do so onsite for an additional cost of $8.



1-Hour Charleston Carriage Tour

Flexible timing, $25 per person

Each tour covers 3-4 miles of Charleston's residential Historic District. They are narrated by Charleston's best city-licensed tour guides. Tours load and depart about every 30 minutes from our stable at 20 Anson Street.

Tickets may be purchased when you register for the conference or onsite at the registration desk.

Detailed Daily Program

NCM Satellite Meeting
Charleston, South Carolina April 19 – 20, 2015

All sessions will be held in the Colonial Room. Posters will be located in the Carolina Ballroom.

The 2015 NCM Satellite Meeting is sponsored by the College of Health Professions, Medical University of South Carolina.

This one-day satellite meeting will gather specialists in the fields of neurophysiology, neurology, neuroimaging, brain stimulation and rehabilitation to share state of the art research into the neural underpinnings of rehabilitation from nervous system injury and disease. The goal is to appeal to both basic and clinical scientists by emphasizing translational research and showing what the future of rehabilitation might look like. The three oral sessions provide a good mix of well-established and new players in the field, and there will be ample time for a poster session, giving everybody the opportunity to discuss their newest results.

Sunday, April 19

17:00 – 19:00 Satellite Registration, Upper Lobby

18:00 – 19:00 Satellite Drinks Reception, Lobby Bar

Monday, April 20

08:00 – 08:30 Satellite meeting coffee service
Welcome/Introduction, Steve Kautz, PhD, Medical University of South Carolina

08:30 - 10:30 **Session 1: Harnessing sensory and motor experience induced plasticity following injury**
Moderator: Aiko Thompson, PhD, Medical University of South Carolina

Motor learning-induced brain plasticity in Parkinson's disease
Beth Fisher, PhD, PT, University of Southern California

Acquisition of a simple motor skill towards improving locomotion after spinal cord injury
Aiko Thompson, PhD, Medical University of South Carolina

Harnessing intermittent hypoxia-induced spinal motor plasticity: breathing and walking after spinal injury
Gordon Mitchell, PhD, University of Florida

Combining biological, bionic and rehabilitation interventions: finding the Goldilocks zones in rodent models of SCI
Simon Giszter, PhD, Drexel University

10:30 - 11:00 **Break**, Carolina Ballroom

11:00 – 13:00 **Session 2: Brain stimulation to enhance plasticity and motor recovery**
Moderator: DeAnna Adkins, PhD, Medical University of South Carolina

Adaptive stimulation approaches to enhancing neuroplasticity and behavioral recovery after brain injury
Randy Nudo, PhD, Kansas University

Directing neural plasticity to treat stroke and other neurological disorders
Michael Kilgard, PhD, The University of Texas at Dallas

Epidural stimulation to enhance motor recovery after stroke
Jeff Kleim, PhD, Arizona State University

Induction of behaviorally significant neuroplastic change with non-invasive brain stimulation
Michael Ridding, PhD, University of Adelaide

13:00 – 15:30 **Lunch and Satellite Meeting Poster Session,** Carolina Ballroom

15:30 – 17:30 **Session 3: Personalization of rehabilitation based on an individual's underlying pathophysiology**
Moderator: Rick Segal, PhD, PT, Medical University of South Carolina

The relationship between post brain lesion neural architecture, neurological deficits and rehabilitation
Leo Bonilha, MD, Medical University of South Carolina

Promoting motor learning after stroke: The potential role of genetic variation in brain-derived neurotrophic factor
Darcy Reisman, PhD, PT, University of Delaware

Neural mechanisms underlying the loss of independent joint control following unilateral brain injury
Jules Dewald, PhD, PT, Northwestern University

Matching upper extremity therapies to the likelihood of meaningful change in individuals with stroke
Catherine Lang, PhD, PT, Washington University

17:30 - 18:00 **Session 4: Wrap up: Question and Answer Session**
All Speakers and Moderators

19:00 – 21:00 **Opening Reception for Annual Meeting**
Please Note: If you registered to attend the Satellite Meeting ONLY and want to attend the reception, tickets can be purchased at the registration desk.

Satellite Meeting Poster Session

Monday, April 20, 2015
Carolina Ballroom
(Mezzanine/Meeting Level)

Theme: Neural Mechanisms of Rehabilitation

S-1 The effect of aerobic exercise coupled with transcranial direct current stimulation on motor learning

Jessica Baer[1], Melissa Kolar[1], Adam Harrison[1], Roger Newman-Norlund[1]
[1]University of South Carolina

S-2 The role of the supplementary motor area in beat-based timing

Li-Ann Leow[1], Jessica Grahn[2]
[1]The University of Queensland, [2]Western University

S-2 Motor unit discharge of the soleus following acute dorsal hemisection in the cat

Christopher Thompson[1], Michael Johnson[1], Francesco Negro[2], Matthew Holmes[1], Jack Miller[1], Dario Farina[2], CJ Heckman[1]
[1]Northwestern University, [2]Georg-August University

S-4 Age-based differences in the effects of a combined iTBS / bihemispheric anodal tDCS approach to the facilitation of motor skill acquisition in the non-dominant upper extremity

Melissa Kolar[1], Jessica Baer[1], Raymond Butts[1], Roger Newman-Norlund[1]
[1]University of South Carolina

S-5 The effect of intermittent maximal contractions on sub-maximal force estimation and regulation post stroke

Katie Bathon[1], Kathleen Bathon[1], Tanya Onushko[1], Jennifer Nguyen[1], Erin McGonigle[2], Natalie Geoffroy[1], Nicholas Ketchum[2], Sandra Hunter[1], Brian Schmit[1], Allison Hyngstrom[1]
[1]Marquette University, [2]Medical College of Wisconsin

S-6 Improved balance body motion and muscle activity after dance-based rehabilitation in individuals with Parkinson's disease: a preliminary study

J McKay[1], Lena Ting[1], Madeleine Hackney[2]
[1]Emory University and Georgia Tech, [2]Emory University School of Medicine / Atlanta VAMC

S-7 Premotor-prefrontal connectivity during motor action selection after stroke

Gillian Harper[1], Steven Cramer[2], Jill Stewart[1]
[1]University of South Carolina, [2]University of California Irvine

S-8 Changes in neural activity patterns during recovery of hand function

Jörn Diedrichsen[1], Jing Xu[2], Naveed Ejaz[1], Ben Hertler[3], Meret Branscheidt[3], Mario Widmer[3], Nathan Kim[2], Michelle Harran[4], Juan Cortes[4], Tomoko Kitago[4], Pablo Celnik[2], Andreas Luft[3], John Krakauer[2]
[1]University College London, [2]Johns Hopkins University, [3]University of Zurich, [4]Columbia University

S-9 Patterns of mirroring and enslaving of finger movements after stroke suggest shared representation of digit movements across hemispheres

Naveed Ejaz[1], Jing Xu[2], Benjamin Hertler[3], Meret Branscheidt[3], Mario Widmer[3], Nathan Kim[2], Michelle Harran[4], Juan Cortes[4], Andreas Luft[4], Pablo Celnik[2], Tomoko Kitago[4], John Krakauer[2], Joern Diedrichsen[1]
[1]University College London, [2]Johns Hopkins University, [3]University of Zurich, [4]Columbia University

S-10 The control of finger individuation and strength recover independently after stroke

Jing Xu[1], Naveed Ejaz[2], Benjamin Hertler[1], Meret Branscheidt[3], Mario Widmer[3], Nathan Kim[1], Michelle Harran[4], Juan Cortes[4], Tomoko Kitago[4], Pablo Celnik[1], Andreas Luft[3], John Krakauer[1], Jörn Diedrichsen[2]
[1]Johns Hopkins University, [2]University College London, [3]University of Zurich, [4]Columbia University

S-11 Expertise in balance is mediated by a set of shared muscle synergies that generalize across motor behaviors

Andrew Sawers[1], Lena Ting[1]
[1]Emory University and Georgia Institute of Technology

S-12 Motor corticospinal excitability of plantarflexors: Is it the same among muscles and hemispheres in healthy adults?

Charalambos Charalambous[1], Mark Bowden[1]
[1]Medical University of South Carolina

S-13 Automaticity of walking: an alternative perspective for locomotor rehabilitation

David Clark[1]
[1]North Florida/South Georgia Veterans Health System

S-14 Effect of peripheral vibration on sensorimotor cortical activity - an EEG study

Na Jin Seo[1], Brian Schmit[2], Kishor Lakshmi Narayanan [3]
[1]Medical University of South Carolina, [2]Marquette University, [3]University of Wisconsin-Milwaukee

S-15 Responsiveness to different visual perturbation characteristics during treadmill walking

Kevin Terry[1], Peter Jo[1]
[1]George Mason University

S-16 Modulation of the interhemispheric inhibition imbalance with active passive bilateral exercises in chronic stroke survivors

Binal Motawar[1], Najin Seo[2]
[1]UWM, [2]MUSC

S-17 Effects of age on retention of locomotor learning

Erin Vasudevan[1], Danica Tan[1]
[1]SUNY Stony Brook University

Annual Meeting Detailed Daily Program

NCM 25th Annual Meeting • April 20 - 24, 2015
Francis Marion Hotel • Charleston, South Carolina

All sessions will be held in the Colonial Room.
Posters will be located in the Carolina Ballroom.

DAY 1 — Sunday, April 19

17:00 – 19:00	**Satellite Registration**
18:00 – 19:00	**Satellite Drinks Reception** – Lobby Bar

DAY 2 — Monday, April 20

08:00 – 08:30	**Satellite Registration**
8:30 – 16:00	**Satellite Meeting**
17:00 – 19:00	**Conference Registration**
19:00 – 21:00	**Opening Reception**, Vincent Chicco's Restaurant

DAY 3 — Tuesday, April 21

08:00 – 10:15 **Session 1, Panel I**
Decoding the reaching and grasping brain
Organizer: Pieter Medendorp
Participants: Pieter Medendorp; Sara Fabbri; Richard Andersen; Hansjörg Scherberger

10:15 – 10:45 **Break** – Carolina Ballroom

10:45 – 13:00 **Session 2, Panel II**
Neuroeconomics of motor control: effort and reward in the healthy and Parkinsonian brain
Organizer: Alaa Ahmed
Participants: John Salamone; Reza Shadmehr; Robert Turner

13:00 – 15:00 **Session 3, Poster 1a**
Lunch
Exhibitor Demo: Blackrock Microsystems – 14:00

15:00 – 17:00 **Session 4, Individual Presentations I**

The neural coding of action in the Purkinje cells of the cerebellum
Participants: David Herzfeld, Yoshiko Kojima, Robijanto Soetedjo, Reza Shadmehr

Simple elements in smart topologies: modeling broad responses in the gaze orientation system
Participants: Iman Haji-Abolhassani, Daniel Guitton, Henrietta Galiana

Illusions affect visuomotor updating in posterior parietal cortex
Participants: Anouk de Brouwer, Jeroen Smeets, Tjerk Gutteling, Ivan Toni, Pieter Medendorp

Basal ganglia signaling flexibly promotes passive and active behavioral control
Participants: Jay Jantz, Masayuki Watanabe, Ron Levy, Douglas Munoz

Distinct motor cortical regions associated with human pelvic floor muscle synergies
Participants: Jason Kutch, Manku Rana, Skulpan Asavasopon, Moheb Yani

Using robotics to characterize the relationship of position sense and kinesthetic impairments after stroke
Participants: Jennifer Semrau, Troy Herter, Stephen Scott, Sean Dukelow

DAY 4 Wednesday, April 22

08:00 – 10:15 **Session 5, Panel III**

Motor memory - the forgotten aspect of motor adaptation and learning: From after-effects and savings to long-term retention
Organizer: Dagmar Sternad

Participants: Nicolas Schweighofer, Gelsy Torres-Oviedo, Valeria Della-Maggiore

10:15 – 10:45 **Break** – Carolina Ballroom

10:45 – 13:00 **Session 6, Panel IV**
Hierarchical organisation of action sequences
Organizer: Scott Grafton
Participants: Joern Diedrichsen, Robert Turner, Konrad Koerding, Xin Jin

13:00 – 15:00 **Session 7, Poster 1b**
Lunch
Exhibitor Demo: Polhemus – 13:30, Tucker-Davis Technologies – 14:00

15:00 – 17:00 **Session 8, Panel V**

Corticostriatal and corticocerebellar function and connectivity in Parkinsons disease
Organizer: Rachael Seidler
Participants: David Vaillancourt, Jay Alberts, Rachael Seidler, Brett Fling

DAY 5 Thursday, April 23

08:00 – 9:40 **Session 9, Individual Presentations II**

Adjustment of gamma motor neuron firing rates in neuromorphic hardware elicits physiological behavior while controlling a cadaveric human finger under kinematic constraints
Participants: Victor Ramon Barradas Patino, C. Minos Niu, Terence Sanger, Gerald Loeb, Francisco Valero-Cuevas

Independence of movement planning and movement initiation in a choice reaction time task
Participants: Adrian Haith, Jina Pakpoor, John Krakauer

Evidence for motor encoding of potential reach targets
Participants: Jason P. Gallivan, Daniel M. Wolpert, J. Randall

Effect of multi-human interaction on motor performance
Participants: Atsushi Takagi, Hirashima Masaya, Daichi Nozaki, Etienne Burdet

A two-layer neural architecture underlies descending control of limbs in Drosophila
Participants: Cynthia Hsu, Vikas Bhandawat

9:40 – 10:10 **Break** – Carolina Ballroom

10:10 – 11:40 **Session 10, Perspective I**

Interplay of sensory and motor systems in motor control
Organizer: Sliman Bensmaia
Participants: Sliman Bensmaia, Tamar Makin, Robert Gaunt

11.40 – 12.10 **NCM Members Meeting**

12:10 – 14:10 **Session 11, Poster 2a**
Lunch
Exhibitor Demo: AMTI – 13:00
Free Time and Excursions (ticketed)

DAY 6 Friday, April 23

08:00 – 10:15 **Session 12, Panel VI**

How the CNS Operates as a Multi-user System
Organizer: Jonathan Wolpaw
Participants: Andrea d'Avella, Aaron Batista, Aiko Thompson

10:15 – 10:45 **Break** – Carolina Ballroom

10:45 – 12:45 **Session 13, Individual Presentations III**

A large scale spiking model of the motor cortex and cerebellum in complex arm control
Participants: Travis DeWolf, Chris Eliasmith

Impact of muscle redundancy on the synergy hypothesis
Participants: Cristiano Alessandro, Robin Urselli, Juan Pablo Carbajal, Robert Riener

How does the sensorimotor system represent a delayed velocity-dependent force field?
Participants: Guy Avraham, Firas Mawase, Lior Shmuelof, Opher Donchin, Ferdinando Mussa-Ivaldi, Ilana Nisky

Paradoxical benefits of dual-task contexts for visuomotor memory
Participants: Joo-Hyun Song, Hee Yeon Im, Patrick Bedard

P3 or Not P3: Assessing the occurrence of the P300 event-related potential during sensorimotor memory updating during an object lifting task.
Participants: Kelene Fercho, Lee Baugh

Execution variability restricts locomotor adaptation in Cerebral Palsy patients
Participants: Firas Mawase, Simona Bar-Haim, Amir Karniel, Lior Shmuelof

12:45 – 14:45 **Session 14, Poster 2b**
Lunch

14:45 – 16:15 **Session 15, Perspective II**
New methods of analysis of population data- relating neural dynamics and Sherrington reductionism
Organizer: Simon Giszter
Participants: Terence Sanger, Maryam Shanechi, John Cunningham

16:15 – 17:30 **Session 16, Keynote Address**
Old and New M1: A tale of two motor areas
Peter Strick, PhD, University of Pittsburgh

17:30 – 18:30 **Closing Drinks Reception** – Lobby Bar

Session 1, Panel I

Tuesday, April 21 8:00 – 10:15

Decoding the reaching and grasping brain

Pieter Medendorp[1], Sara Fabbri[2], Richard Andersen[3], Hansjörg Scherberger[4]

[1]Radboud University Nijmegen, [2]Western University, [3]California Institute of Technology, [4]German Primate Center

Reaching and grasping are a fundamental characteristics of primate motor behavior. However, understanding the neural mechanisms by which these interactions are achieved is still a major challenge. Information about the object, like its location, size, shape, and orientation can be obtained through various sensory modalities and needs to be integrated with information about the effector systems, like arm and fingers, to compute the action plan. While parietofrontal cortex is involved, there is debate on how this information is represented in the neuronal populations and how it is mapped onto the two-dimensional cortical surface. In recent years, several novel decoding approaches have been employed to identify these cortical constraints in humans and non-human primates based on imaging data and physiological recordings. This session will inform NCM members about these current findings and provide a platform to discuss the pros and cons of using novel representational and decoding methods to understand physiology and develop neuroprosthetics. MEDENDORP will start the session with a brief overview. Subsequently, he will discuss the mechanisms for effector and target selection for reaching and grasping in the human brain. Combining multi- and univariate fMRI measures, he will demonstrate effector-related representations in the parietofrontal network. Furthermore, he will describe how visual and somaesthetic targets are encoded in gaze- and body-centered reference frames in cortical grasp and reach circuits. FABBRI will provide human neuroimaging data on the representation of object properties during passive viewing and grasping of 18 different objects. Using a data-driven multivariate approach, she will show a visuomotor gradient from ventral to dorsal stream regions mainly driven by the representation of visual information about object elongation and by the motor information about the number of digits involved in the grasping action. ANDERSEN will discuss the high level representation of reach and grasp intentions derived from chronic recordings from populations of single neurons in a tetraplegic subject. The goal coding of single neurons show effector specificity of imagined left and right limb and saccadic movements; grasp activity is decoded related both to object shapes and the intent to form different grasps. Furthermore, he will use population decoding in brain control tasks for reaching and grasping with a robotic limb, demonstrating the potential for using signals for neuroprosthetic applications. SCHERBERGER will describe experiments in macaque monkeys trained to grasp ~50 different objects of various size, shape, and orientation. Using, e.g., hierarchical cluster analysis, he will demonstrate distinct roles of the neuronal populations in AIP, F5, and M1 for processing object features and hand kinematics. Furthermore, he will provide a unified interpretation of the data of the four speakers in preparation of a general discussion.

Session 2, Panel II

Tuesday, April 21 10:45 – 13:00

Neuroeconomics of motor control: effort and reward in the healthy and parkinsonian brain

Alaa Ahmed[1], John Salamone[2], Reza Shadmehr[3], Robert Turner[4]
[1]University of Colorado, [2]University of Connecticut, [3]Johns Hopkins University, [4]University of Pittsburgh

If the purpose of a movement is to improve the state of the body, then each movement is a decision that balances the rewards at stake with the effort it takes to make the movement. Similar to an economic decision, a movement may seek to maximize reward while minimizing effort. Over the past two decades, economists have increasingly turned to neuroscience as a means to understand the neural mechanisms underlying decision making. This has given rise to the new field of neuroeconomics, a field that has grown over the past decade, providing a framework to consider the neural basis of decision making. However, its potential to contribute to our understanding of how the brain makes movements has been largely untapped. For example, it is unclear how the brain evaluates the effort associated with performing a movement, and how this evaluation may be combined with expected rewards. Understanding the neural basis of effort in the context of motor control is important because of its relevance to the movement disorder in Parkinson's disease (PD). The goal of this panel is to introduce a neuroeconomic framework for control of movements, evaluate the neural basis of that framework in rodent and non-human primate models, and then apply the framework to the motor disorder in PD. We will present studies from rodents and non-human primates that highlight the mechanisms with which the basal ganglia evaluates effort, and then consider the movement disorder in Parkinson's disease in the framework of neuroeconomics. The Panel will begin with a presentation by Alaa Ahmed, describing a mathematical framework which considers economic models of effort and reward, with a focus on the relationship between effort and metabolic costs of movements. Next, John Salamone will present results from a comprehensive body of work on the neurochemical interactions regulating effort-related decision making in rodents. Robert Turner will transition the discussion to control of movements in non-human primates and present lesion and single cell data from the basal ganglia during control of movements. To conclude, Reza Shadmehr will present results on effort-based decision making in PD, focusing on how the disease affects the subjective evaluation of effort and the role of brain stimulation in altering these effort costs. Throughout the panel, findings will be presented in the context of a neuroeconomic framework, with the goal of understanding movement decision making in the healthy and Parkinsonian brain.

Session 4, Individual Presentations I

Tuesday, April 21 15:00 – 17:00

The neural coding of action in the Purkinje cells of the cerebellum

David Herzfeld[1], Yoshiko Kojima[2], Robijanto Soetedjo[2], Reza Shadmehr[1]

[1]Johns Hopkins University, [2]Washington National Primate Center, University of Washington

Execution of accurate eye movements depends critically on the cerebellum. This observation suggests that Purkinje cells (P-cells) should encode saccade metrics. Yet, this encoding has remained a long-standing puzzle as firing of P-cells show no obvious modulation with respect to saccade speed or direction. How can P-cells be involved in control of the eye if their discharge is poorly correlated with saccade metrics? We analyzed simple spike activity of 72 oculomotor vermis (OMV) P-cells from 5 monkeys during saccades of various amplitudes and direction. We found that P-cells could be broadly separated into two classes: bursting, or pausing during a saccade. However, neither groups in isolation had a firing pattern that matched the time course of a saccade. Indeed, the cells were poorly modulated by saccade speed or direction, confirming earlier observations. P-cells in OMV project to caudal fastigial nucleus (cFN), where about 50 P-cells converge onto a single cFN cell. We computed what a typical cFN cell would receive from OMV by randomly selecting 50 P-cells and estimating the resulting inhibitory post-synaptic current (IPSC) at cFN. The result unmasked a remarkable feature: the time course of the IPSC precisely predicted the time course of the saccade. Therefore, while individual P-cell discharge was not modulated by state of the eye, the population induced inhibition at the cFN predicted kinematics. We asked whether P-cells were organized in how they projected onto the output nucleus. The key new idea was to use cerebellar complex spikes (CS) as a coordinate system with which to organize the simple spikes of the P-cells. We induced post-saccadic error by displacing the target during the saccade, and then measured the probability of complex spikes (CS) as a function of direction of the error. For each P-cell the direction that produced that largest probability of CS in the post-saccade period was labeled CS-on. We found that when simple spikes were organized with respect to the P-cell's CS, the resulting IPSC precisely predicted both speed and direction of the saccade ($R^2 = 0.95$). In summary, our results suggest two new principles of cerebellar function: 1) transformation of efference copy into a prediction of kinematic state does not occur in individual P-cell activity, but via combined activity of pause and burst P-cells onto the nucleus, producing an inhibition that precisely predicts the real-time state of the eye during a movement. 2) The anatomical projections from P-cells to nucleus neurons are likely not random, but organized into modules that consist of approximately equal number of bursting and pausing P-cells, all with similar complex-spike properties. This second principle predicts that the specific P-cells that project to a nucleus neuron are largely selected due to the influence of their inputs from the inferior olive.

Simple elements in smart topologies: modeling broad responses in the gaze orientation system

Iman Haji-Abolhassani[1], Daniel Guitton[1], Henrietta Galiana[1]

[1]McGill University

In studying the gaze orientation system, numerous experiments have been carried out each probing and eliciting a subset of the responses of the gaze orientation system. These responses include: the fast phase (saccade), the slow phase, pursuit, vestibular compensation during slow phase (VOR), vestibular compensation during fast phase, head-fixed/free gaze orientation, gaze orientation in the light/dark, etc. (Robinson 1981, Galiana 1984, Tomlinson and Bahara 1986, Phillips et al. 1995, Kardamakis et al. 2010, ...). As a result of these experiments, a massive amount of behavioral and central responses is available for inspection in the literature. The diversity of the mentioned responses has resulted in a wide range of proposed models addressing different aspects of the gaze orientation system. The goal of this research is to integrate the available behavioral and central knowledge of the gaze orientation system into one 'shared' controller (shared for different tasks). This will enable us to apply the model to real-life scenarios, many of which involve the simultaneous recruitment of different stimuli together. To do so, this controller should accept both visual and vestibular inputs, fuse them, and generate behavioral (platform trajectories) and central (firing rates) responses that match the reported experiments. We call this new model the Sensory-Fusion Model (SFM) for gaze orientation. The SMF model is a gaze error feedback controller in which all of the involved platforms collaborate to null the shared gaze error and stabilize the gaze on target. The SMF shares a limited number of neural centers in the brainstem that are 'known' to be involved in gaze orientation, but uses them efficiently in a topology that is consistent with known connections and projections. This successfully replicates 'the widest range of behavioral and central responses' that have ever been replicated using a single model for gaze orientation. These responses include but are not limited to all of the ones mentioned earlier. Finally the model will be used to replicate lesions and perform predictions for specific scenarios. The analysis of the model and its responses yield invaluable results pertaining to how gaze orientation data should be classified and analyzed. In a broader sense, the SMF model sheds light on how the CNS possibly does other tasks similar to the gaze orientation system (e.g., limb control and locomotion) by using 'simple elements in smart topologies'.

Illusions affect visuomotor updating in posterior parietal cortex

Anouk de Brouwer[1], Jeroen Smeets[2], Tjerk Gutteling[1], Ivan Toni[1], Pieter Medendorp[1]

[1]Radboud University Nijmegen, [2]VU University Amsterdam

Visual illusions are reported to affect perceptual judgments more than goal-directed movements. During goal-directed movements, targets need to be specified relative to the observer, and internally updated when the observer moves, irrespective of visual context. This process, called visuomotor updating, occurs in the posterior parietal cortex (PPC; e.g., Merriam, Genovese, & Colby, Neuron 2003). If visual context is processed exclusively in the ventral visual stream, then visuomotor updating should not be influenced by visual contextual illusions. To test this hypothesis, we designed a double-step saccade task in which the spatial dimensions of the second saccade must be computed based on the initial retinal coordinates of the target and the metrics of the intervening first saccade. We exploited this task in two ways: (1) a behavioral experiment in which we investigated the effect of a visual contextual illusion on visuomotor updating, and (2) an fMRI experiment in which we investigated the effect of a visual illusion on the neural representation of the updating process in the PPC. In our task, subjects briefly viewed a horizontal Brentano version of the Müller-Lyer illusion with a target at its middle vertex, while fixating at one of the two endpoints of the illusion. Next, the eyes' fixation point moved to a position straight above or below the target. After a delay, subjects made a saccade to the remembered position of the target. Behavioral results showed that the updating process is distorted by the Brentano illusion; the second saccade landed to the left or right of the actual target position, depending on the configuration of the illusion. To reveal a neural correlate of this finding, we exploited the retinotopic organization of the PPC (e.g., Medendorp, Goltz, Vilis, & Crawford, J Neurosci 2003; Sereno, Pitzalis, & Martinez, Science 2001). If the neural representation of the target is affected by the illusion, a contralateral bias in the BOLD response should arise during the planning of the second saccade. Our results indeed showed that in right PPC BOLD amplitude was higher when planning a saccade to a target that is remembered to the left (than to the right) of its actual position. Vice versa, left PPC showed a higher BOLD amplitude when planning a saccade to a target that is remembered right of its actual position, although the physical position of the target was always straight up or down from the end position of the first saccade. In conclusion, visuomotor updating for saccades and the corresponding neural representations are affected by a visual contextual illusion, showing that the processing of contextual information is not restricted to the ventral stream, but also affects egocentric processing in the posterior parietal cortex.

Basal ganglia signaling flexibly promotes passive and active behavioral control

Jay Jantz[1], Masayuki Watanabe[1], Ron Levy[1], Douglas Munoz[1]

[1]Queen's University

Recent brain imaging studies have implicated the basal ganglia (BG) as part of the task-dependent modulation of large-scale frontal-parietal and default networks during flexible control. The frontal-parietal network facilitates externally driven goal-directed tasks (i.e., active control), which is juxtaposed by the default network that is attenuated during active control, but facilitates internalized events such as freethinking and daydreaming (i.e., passive control). However, examining the related functional changes within the BG network has remained a challenge. We have approached this by probing the influence of BG input (subthalamic nucleus, STN; and caudate nucleus, CN), and output (substantia nigra pars reticulata, SNr) nuclei in monkeys, while saccadic eye movements - elicited either spontaneously during passive control or goal-directed during active control - were used as a behavioral indicator of BG efferent signals. We describe neurophysiological evidence of concerted changes across the BG circuit according to active or passive control states, such that CN and STN electrical stimulation both revealed diametric effects on saccade initiation, while the SNr did not, and their comparison revealed coordinated increases in facilitatory striato-nigral and subthalamo-nigral pathways during passive control but inhibitory pathways during active control. We suggest that this BG signaling should be included in a larger framework of default network control and behavior, which in the context of saccade movements could prime the circuit for fast automatic saccades during a passive state, and slower accurate voluntary saccades during an active state.

Distinct motor cortical regions associated with human pelvic floor muscle synergies

Jason Kutch[1], Manku Rana[1], Skulpan Asavasopon[2], Moheb Yani[1]

[1]University of Southern California, [2]Loma Linda University

Modulating pelvic floor muscle activity in relation to activity in other lower limb and trunk muscles is a critical contributor to continence and pelvic stability during many postural tasks. However, the neural structures responsible for the synergistic coactivation of pelvic floor muscles with voluntary contraction of trunk/lower limb muscles are poorly understood, despite the important role that the control of these muscles play in prevalent clinical conditions (Kilpatrick et al., 2014). We have recently shown that activity in primary motor cortical regions in the medial wall of the precentral gyrus is associated with the coactivation of pelvic floor muscles during voluntary contraction of gluteal muscles (Asavasopon et al., 2014). Here we further interrogate cortical mechanisms of pelvic floor muscle control by examining the even more surprising coactivation of pelvic floor muscles with voluntary toe contraction in healthy human males. We first demonstrate, using electromyographic recordings from the pelvic floor and toe (flexor hallicus longus - FHL), that the pelvic floor contracts automatically during voluntary toe contraction. Using functional magnetic resonance imaging (fMRI) during muscle contraction tasks, we then localized two important motor cortical regions: one that was preferentially active during voluntary toe contraction (posterior region) and one that was active during both voluntary pelvic floor contraction and voluntary toe contraction (anterior region). We then show, using transcranial magnetic stimulation, that the FHL was preferentially activated by the posterior region while the pelvic floor was equally activated by both the anterior and posterior regions of primary motor cortex. Finally, in a repository fMRI dataset of 48 men, we estimated the functional connectivity of the anterior region and posterior region, and found that the anterior region has preferential connectivity to the insula, whereas the posterior region has preferentially connectivity to the primary somatosensory cortex, frontal cortex, and parietal cortex. These results demonstrate that adjacent motor cortical regions project to pelvic floor muscles but are not functionally equivalent, and suggest that there are at least two regions of motor cortex that could contribute differently to dyscoordination of pelvic floor muscle activity. References Asavasopon S, Rana M, Kirages DJ, Yani MS, Fisher BE, Hwang DH, Lohman EB, Berk LS, Kutch JJ (2014) Cortical Activation Associated with Muscle Synergies of the Human Male Pelvic Floor. The Journal of Neuroscience 34:13811-13818. Kilpatrick LA, Kutch JJ, et al., Mayer EA (2014) Alterations in Resting State Oscillations and Connectivity in Sensory and Motor Networks in Women with Interstitial Cystitis/Painful Bladder Syndrome. The Journal of Urology 192:947-955.

Using robotics to characterize the relationship of position sense and kinesthetic impairments after stroke

Jennifer Semrau[1], Troy Herter[2], Stephen Scott[3], Sean Dukelow[1]

[1]University of Calgary, [2]University of South Carolina, [3]Queen's University

Historically, proprioception has been divided into two sub-modalities: position sense - sense of static limb location, and kinesthesia - dynamic sense of limb motion. While both are integral parts of sensorimotor control, it is unclear whether they are processed independently or are highly integrated. Recently we have identified that impairments in proprioception are very common after stroke. Through use of a stroke model, we aimed to characterize the relationship between position sense and kinesthesia to determine whether they are independent or highly integrated. We evaluated position sense and kinesthesia using a robotic exoskeleton in 211 subjects with unilateral stroke at one week post-stroke. To evaluate static position sense, subjects performed a robotic position matching (PM) task where the robot moved the stroke affected arm to one of nine locations in the workspace. Subjects were instructed that when the robot stopped moving, to mirror-match the location where the robot moved their unaffected arm. To evaluate kinesthesia, subjects performed a robotic kinesthetic matching (KIN) task. The robot moved the affected arm at a preset speed, direction and magnitude to one of three targets. Subjects were instructed to mirror-match the robotic movement with their unaffected arm as soon as they felt the robot begin to move. PM and KIN data was quantified using spatial (PM, KIN) and temporal (KIN) parameters known to evaluate position sense and kinesthesia. We found that 50% of subjects had impaired position sense and 67% had impaired kinesthesia. Upon closer examination of the relationship between PM and KIN, we found that 6% of our subjects had only position sense deficits (without kinesthetic deficits), while 24% of our subjects had only kinesthetic deficits (without position sense deficits). Preliminary results demonstrated that correlations of spatial parameters of PM and KIN (range: $r = 0.33$-0.67) were significantly higher than correlations of spatial parameters of KIN and temporal parameters of PM (range: $r = 0.17$-0.50) (t-test, $p < 0.05$). Our results suggest that position sense impairments nearly always co-occur with kinesthetic impairments, while the converse is not necessarily true. We observed that kinesthetic deficits more commonly occurred without the presence of position sense deficits, suggesting that some kinesthetic information may be processed independently from position sense. Additionally, we observed that correlations between spatial (KIN) and spatial (PM) parameters were significantly higher than correlations between temporal (KIN) and spatial (PM) parameters, suggesting a possible separation of temporal and spatial processing. These results suggest that while position sense and kinesthetic information is highly integrated, aspects of kinesthetic processing may be independently processed from static position sense information.

Session 5, Panel III

Wednesday, April 22 08:00 – 10:15

Motor memory – the forgotten aspect of motor adaptation and learning: From after-effects and savings to long-term retention

Dagmar Sternad[1], Nicolas Schweighofer[2], Gelsy Torres-Oviedo[1], Valeria Della-Maggiore[3]

[1]Northeastern University, [2]University of Southern California, [3]University of Buenos Aires

Learning is only achieved when practice-induced behavioral improvements lead to neuroplastic changes with long-term persistence. Regarded as a form of procedural memory, retention of motor skills is likely mediated by different neural mechanisms than declarative memory, as seminal studies on the patient HM suggest. Nevertheless, long-term retention of a motor skill has received relatively little systematic study in recent years, even though lasting neuroplasticity is the holy grail of any clinical intervention. In motor adaptation studies, after-effects document that the internal representation has changed, but they quickly attenuate and baseline performance reappears. Lasting neural changes are reflected in savings, the accelerated re-learning of the same task. However, successful therapy requires that behavioral changes persist in scenarios outside the clinic. How can such learning be achieved? The symposium will present behavioral, modeling and neuroimaging results, with basic and clinical questions to shed light on the processes of motor memory. Which aspects of a motor skill are retained and which are forgotten? What conditions further long-term retention? Do adapting a known skill and learning a novel skill involve the same neuroplastic processes? Dagmar Sternad presents longitudinal studies on practice and retention of a novel skill, including self-guided practice and targeted interventions. Detailed analyses reveal spatio-temporal changes of performances during extensive practice and their remarkable persistence after months and years. Results reveal multiple time scales of learning and forgetting and conditions that facilitate long-term retention. Nicolas Schweighofer presents a computational model and data that address two controversial questions: Are savings due to increase in learning rate, or due to recall of previous memories? Is forgetting due to passive decay or due to rapid stochastic decay? The model generates rapid changes during re-adaptation or during forgetting in error clamp conditions by switching among internal models, leaving memories protected. Valeria Della-Maggiore presents functional and anatomical evidence from longitudinal studies conducted at different time scales, indicating that visuomotor adaptation is associated with consolidation and near perfect long-term retention after one year without practice. These studies suggest that adaptation shares common features with motor skill learning. Gelsy Torres-Oviedo presents learning rates and forgetting in young and old adults when learning to walk on a split-belt treadmill. Based on results that healthy aging causes motor memories to be more fragile, she will argue that forgetting leads to the slower learning rates in older populations. Nevertheless, older adults recall the learned walking pattern, as indicated by faster re-learning after several weeks. These results suggest that forgetting during acquisition and long-term recall might be dissociable processes.

Session 6, Panel IV

Wednesday, April 22 10:45 – 13:00

Hierarchical organisation of action sequences

Scott Grafton[1], Joern Diedrichsen[2], Robert Turner[3], Konrad Koerding[4], Xin Jin[5]

[1]University of California, Santa Barbara, [2]University College London, [3]University of Pittsburgh, [4]Northwestern University, [5]Salk Institute

How are complex action sequences represented and controlled by the nervous system? Recent neurophysiological results and models suggest that populations of neurons interact as dynamical systems, which produced invariant spatio-temporal patterns of neural activity. In contrast to this "flat" view of sequential behaviour, there is considerable evidence that action sequences are organised in a hierarchical fashion - and throughout multiple cortical and subcortical systems. The panel brings together a number of groups using neurophysiology, neuroimaging, and computational methods to understand how the nervous system combines multiple action elements combined into temporal groupings, or "chunks." GRAFTON will introduce the topic, provide a brief survey of different methods for assessing the presence of chunking and serve as moderator. KOERDING will present work that asks what the objective of chunking is. The modelling assumes that there is an interplay between the cognitive cost of storing information and the desire to optimize the movement trajectory. It is based on the assumption that only within each chunk real optimization is possible. This framework explains a number of parameter evolutions over the course of sequence learning. TURNER will describe results from a series of studies of the neural control of action sequences in non-human primates. Convergent evidence from both neurophysiology and transient inactivation experiments suggest that the basal ganglia play an essential role in the execution of recently-learned motor sequences. The basal ganglia appear to play a far less important role, however, during the execution of well-learned sequences. JIN will present work that dissects the molecular and neural mechanisms of action chunking in the basal ganglia circuitry of mice. By combining behavioural microstructure analysis, in vivo neurophysiological recording, genetic and optogenetic tools, the studies reveal the cell-type and pathway-specific contribution of basal ganglia circuits in chunking and performing action sequences. DIEDRICHSEN will present new behavioural and neuroimaging data that that looks at the representation of action sequences in the human neocortex. By analysing the dissimilarities between the fine-grained activity patterns elicited by different finger sequences, the representational structure of such sequence representation can be revealed. While primary motor cortex represents transitions between pairs of fingers in unique activity patterns, premotor and parietal areas represent the sequence as a whole or in terms of its constituent action chunks.

Session 8, Panel V

Wednesday, April 22 15:00 – 17:00

Corticostriatal and corticocerebellar function and connectivity in Parkinson's disease

David Vaillancourt[2], Jay Alberts[3], Rachael Seidler[1], Brett Fling[4]

[1]University of Michigan, [2]University of Florida, [3]Cleveland Clinic, [4]Oregon Health & Science University

It is well established that the basal ganglia and cerebellum regulate motor control. In Parkinson's disease (PD), most models still consider PD as a disease affecting the basal ganglia and treatments remain focused on modulating the basal ganglia and their cortical networks. The role of the basal ganglia in PD has mainly been driven by studies from pathology, pharmacology, animal models and more recently from human neuroimaging. While this framework remains fundamental in motor systems neuroscience, there is a developing body of evidence from the field of neuroimaging that also points to functional disease changes in the cerebellum. In particular, it is becoming evident that the connectivity between the cerebellum and cortex is abnormal in PD, and that the blood oxygen level dependent signal is consistently impaired within the cerebellum in PD compared with control individuals. Further, radiotracer imaging using cholinergic markers demonstrates that the cerebellum is functioning abnormally in PD and may be fundamental in the onset of falls and gait abnormalities. This new set of findings has been derived from various forms of neuroimaging techniques including resting-state connectivity, task-based fMRI, diffusion weighted imaging, and positron emission tomography. Key discoveries have also been made which demonstrate that connectivity within the basal ganglia-thalamo-cortical and cerebellar-thalamo-cortical circuits are impaired in PD, and that deficits in gait may be linked to the cerebellum. This session brings together four different laboratories that investigate this problem from diverse perspectives. Dr. Seidler will characterize recent work on the connectivity of the basal ganglia-thalamo-cortical and cerebellar-thalamo-cortical networks in the resting brain of older adults and PD patients. Dr. Vaillancourt will present recent work comparing PD and atypical Parkinsonism using task-based fMRI and different forms of structural MRI, which provide clear patterns of degeneration across the basal ganglia, cortex, brainstem, and cerebellum that are specific to each disease. Dr. Fling will present evidence for altered structural and functional connectivity within the locomotor neural network in people with PD who freeze, reflecting a loss of more automated control of gait by the basal ganglia and increased control via cortico-cerbellar and cortico-pontine pathways. Dr. Alberts will present new findings on exercise interventions aimed at altering basal ganglia and cerebellar activity. This collection of lectures supports the view that the cerebellum is critical in our understanding of PD and in particular symptoms related to gait.

Session 9, Individual Presentations II

Thursday, April 23 08:00 – 9:40

Adjustment of gamma motor neuron firing rates in neuromorphic hardware elicits physiological behavior while controlling a cadaveric human finger under kinematic constraints

Victor Ramon Barradas Patino[1], C. Minos Niu[1], Terence Sanger[1], Gerald Loeb[1], Francisco Valero-Cuevas[1]

[1]University of Southern California

Static and dynamic gamma motor neurons determine the intensity of a muscle spindle's response to changes in its length and velocity, respectively. The activity of the gamma motor neurons can be quantified and parameterized by their firing rate. Previously, neuromorphic hardware has been used to simulate the interactions between motor neuron pools, muscle spindles, and muscle fibers through computational models. We reported that the conjunction of this system with a single-joint, tendon-driven robotic finger, as a controller-plant pair, led to an emergent stretch reflex. This result was subsequently validated by substituting the robotic system by a cadaveric human finger, which introduced real biomechanics into the control loop. We have now extended that same paradigm to test and evaluate the effect of different combinations of gamma static and dynamic gains on the resulting simulated EMG and spindle outputs. We replicated the traditional ramp and hold perturbation paradigm performed on human subjects using a servomechanism to drive both the robotic and cadaveric fingers. In the case of two cadaveric finger specimens, the perturbation was applied around the metacarpophalangeal joint of the index finger, inducing a flexion-extension motion, while the rest of the finger joints were immobilized by a splint. The experiment was performed under two different perturbation conditions, in which the displacement of the fingers remained the same, but position ramps were delivered at two different speeds, slow (motion completion in 2 s) and fast (motion completion in 0.25 s). Each trial in the experiment was defined by a pair of gamma static and dynamic gains, determined by every possible combination of both parameters, considering 11 equally spaced levels for each, from 0 to 200 spikes/s. A comparison to published human data shows that a subset of combinations of gamma static and dynamic drives is able to account for physiologically realistic behavior of the EMG and muscle spindle traces. Having identified the set of plausible physiological values for the gamma drives, our neuromorphic system can now be used to disambiguate the spinal mechanisms and interactions responsible for healthy and pathologic function. Research reported in this publication was supported by the National Institute of Arthritis and Musculoskeletal and Skin Diseases of the National Institutes of Health (NIH) under Award Numbers AR050520 and AR052345 to FVC, and K12HD073945 to JMF. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

Independence of movement planning and movement initiation in a choice reaction time task

Adrian Haith[1], Jina Pakpoor[2], John Krakauer[1]

[1]Johns Hopkins University, [2]University of Cambridge

The reaction time (RT), between presentation of a stimulus and initiation of movement, is a ubiquitous behavioral measure in psychology and neuroscience. However, precisely what determines the RT remains poorly understood. A typical RT for reaching movements is around 250ms. However, only around 100-150ms of this can be accounted for by signaling delays. Why is the RT usually so much longer? It is commonly assumed that the additional delay in the RT is attributable to planning; before a movement can be executed, the brain must first perform time-consuming computations in order to compile an appropriate sequence of motor commands. Here, we suggest an alternative view: that movements are in fact always prepared within 150ms but are only initiated some time later, at a time that is independent of the state of preparation. We performed an experiment to independently measure the time courses of movement preparation and initiation in human subjects. In an 8-target choice reaction time task (Free RT condition), the average reaction time was 213±22ms (N=10 subjs). In a subsequent phase of the experiment, we tested whether subjects truly required this much preparation time, or whether they could generate accurate reaching movements at lower RTs. We employed a timed-response paradigm (Ghez et al., Exp Brain Res, 1996) to manipulate subjects' RT by varying the time at which the target was presented relative to a pre-specified movement initiation time (Forced RT condition). Subjects exhibited a clear trade-off between their RT and the accuracy of their movement. Movements with an RT less than 100ms were initiated in a random direction. As the RT increased beyond 100ms, performance steadily improved, with the probability of moving towards the correct target reaching an asymptote by around 150ms. Therefore subjects could consistently move accurately at reaction times well below those they voluntarily selected under Free RT conditions. Critically, even in the Free RT condition, movements appeared to occasionally be initiated before they were fully prepared; subjects occasionally voluntarily initiated movements at very low RTs (less than 150ms) and, just as in the Forced RT condition, these low RT movements were erroneous. In fact, the overall speed-accuracy tradeoff we observed in the Free RT condition was very similar to that observed in the Forced RT condition. This finding is incompatible with a serial organization of action in which movements are only initiated once they are fully prepared. Instead, our data are more consistent with a model in which the timing of movement initiation is determined independently of preparation. The delay between the mean time at which movements became planned and the mean initiation time may act as a safety margin to minimize the possibility that initiation could inadvertently occur before planning is complete.

Evidence for motor encoding of potential reach targets

Jason Gallivan[1], Daniel M. Wolpert[2], J. Randall Flanagan[1]

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Recent and highly influential work has shown that activity in sensorimotor areas of the brain encodes multiple potential reach targets prior to deciding between, and then reaching towards, one of these targets (Cisek & Kalaska, Neuron, 2005). One provocative interpretation of this activity is that it reflects competing movement plans prepared for multiple potential targets. However, an equally plausible interpretation of this neural activity is that it encodes the sensory properties of the potential targets (e.g., their spatial locations or directions) prior to any movement plan being formed. Recent behavioural studies showing 'spatial averaging' when reaching towards multiple potential reach targets are equally equivocal about the extent to which the brain represents multiple possible movements or multiple targets. Determining which of these two accounts is correct is critical to understanding the underlying mechanisms by which the brain initially represents and makes decisions between competing options. Here we provide direct evidence, using two separate reaching tasks that enable us to unequivocally test between these competing interpretations, that the brain fully prepares multiple potential movements before deciding between them. In the first study, participants were required to initiate a reaching movement towards two potential targets, one of which was cued as the target after movement onset, resulting in a later corrective movement to that target. Previous studies have shown that participants, under similar circumstances, initially aim their reach in the average direction of the two targets. By including an obstacle that affects the movement to one of the targets, but not a straight- ahead movement between targets, we were able to dissociate the visual position of that target from its associated movement path. In these trials we found that individuals generated initial movement directions consistent with a 'motor' averaging of potential movement paths rather than 'visual' target locations. In the second study, we show why preparing multiple movements is computational advantageous. Using a reaching task in which movements were initiated only after one of two potential targets was cued, we show that the movement generated for the cued target borrows components of the movement that would have been required for the other, competing target; an interaction that can only arise if multiple potential movements are specified in advance and which, as we demonstrate, reduces the time required to launch a given action plan. Our findings suggest that this 'co-optimization' of reach plans is highly automatic, occurs outside conscious awareness, and may be a mechanism for minimizing the working memory requirements associated with action planning. Taken together, these two studies provide direct support for the influential idea that the brain prepares multiple competing movement plans in advance of deciding between targets.

Effect of multi-human interaction on motor performance

Atsushi Takagi[1], Hirashima Masaya[2], Daichi Nozaki[3], Etienne Burdet[1]

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We recently demonstrated how partners related by a spring connection can track a randomly moving target better than individuals training alone, so that even the better partner improves with the worse (Ganesh et al. Scientific Reports 2014). We wanted to examine whether this improvement in tracking would hold with more interacting partners, or whether they would interfere negatively. Thus, we recruited 68 subjects to form 10 pairs and 12 groups of four. Each subject used a Phantom 1.5HF haptic interface to control a cursor on a monitor and track a pseudo-randomly moving target. The trials were alternated between disconnected trials, where each subject practiced alone, and trials in which they were connected by a compliant spring. In the groups of four, we examined four combinations of three subjects. Surprisingly, the tracking performance increased with the number of connected partners, so that better performance was obtained with three than two and with four than three connected partners. Furthermore, the performance improvement of subjects at the end of the trial was equivalent to the improvement 5 seconds in; subjects were able to identify their performance, relative to their partners', rapidly in 5 seconds. The duration taken for this identification was similar for two, three and four connected partners; this suggests that interacting with multiple partners is cognitively as complex as with one partner and may rely on the same computational process. These results highlight the importance and efficiency of motor interactions between humans, which has been studied little relative to verbal or gestural communication.

A two-layer neural architecture underlies descending control of limbs in Drosophila

Cynthia Hsu[1], Vikas Bhandawat[1]

[1]Duke University

To execute appropriate, fast and precise movements, the nervous system must not only integrate multiple streams of sensory information and make behavioral decisions, it also must recruit complex multi-jointed limbs in the correct order.Considerable progress has been made in understanding how a given region of the brain controls a single behavior driven by a single stimulus. However, motor control is distributed across distinct circuits in the brain that work in concert to control behavior. In mammalian systems, the large number of neurons distributed across many brain regions presents an impediment to obtaining an integrated view of motor control. In this study, we took advantage of Drosophila as a model system. Like humans, Drosophila has also solved the problem of integrating multiple streams of information and controlling multi-jointed limbs, but does so with far fewer neurons which makes it possible for us to understand principles of descending motor control at the level of single neurons.We retrogradely labeled descending neurons (DNs) by bulk loading DNs axons with a dye. We found that only ~900 DNs distributed over 7 clusters are responsible for all descending control in Drosophila. We employed a multi-pronged approach to the study of descending motor control. To understand how sensory information from multiple modalities and instructions related to movements are organized in the descending neuron population, we have developed methods to perform in-vivo whole-cell patch clamp recordings in the fly brain while tracking the fly's leg movements and stimulating the fly with stimuli from multiple modalities. We have also developed methods to genetically activate and inactivate known population of DNs to assess their role in motor control. Finally, to understand the circuit architecture underlying descending control, we will use an ex-vivo preparation to establish connectivity between upstream circuits in the brain, DNs and circuits in the thoracic ganglia. We hypothesize that descending control in Drosophila is based on a two-layer neural architecture. One set of DNs (driver DNs or DDNs) are strongly-tuned to sensory stimuli, directly contact motor neurons and initiate movement. These DNs also send axon collaterals to activate a second set of DNs (modulatory DNs or MDNs). MDNs are not tuned to sensory stimuli, and are activated following movement initiation. The activity in these DNs is strongly correlated to the speed of movement. Activating MDNs in ex-vivo preparations result in a large increase in the excitability of motor neurons.

These experiments suggest that DDNs send specific motor commands to the body motor circuits and MDNs modulate ongoing movements. Overall, our experiments support a two-layer circuit architecture underlying descending motor control.

Session 10, Perspective I

Thursday, April 23 10:10 – 11:40

Interplay of sensory and motor systems in motor control

Sliman Bensmaia[1], Tamar Makin[2], Robert Gaunt[3]

[1]University of Chicago, [2]Oxford University, [3]University of Pittsburgh

The neural control of movement requires cooperation between the motor and sensory systems. In particular, somatosensory representations are tightly linked with motor control. The aim of the panel will be to investigate the interactions between somatosensory and motor systems in motor control. First, we will describe proprioceptive representations in S1 and the functional interactions between S1 and M1 in intact non-human primates. Then, we will discuss the critical role that motor outputs might play in shaping representation in SI based on results obtained from human amputees. Finally, we will provide a compelling example of the importance of proprioception during the online guidance of movements using results from a human study with a brain-machine interface. Sliman Bensmaia will describe a study, carried out in collaboration with Nicholas Hatsopoulos, in which his team simultaneously recorded neuronal responses in SI and M1 of non-human primates as well as their hand kinematics as the animals performed a grasping task. From these data, the team investigated how hand movements are represented in somatosensory and motor cortex. In brief, S1 and M1 neurons respond to complex hand movements and conformations rather than to individual joint movements. Second, they investigated the dynamics of communication between SI and M1 during the task and showed that the two cortices communicate bidirectionally with very systematic and repeatable dynamics. These results suggest a close interplay between M1 and S1 during motor control. Tamar Makin will focus on the case of proprioceptive phantom sensations following arm amputation. By asking individuals to perform movements with their phantom hands in a 7T MRI scanner, Makin will show preserved representation of SI hand topography, even though peripheral inputs from the hand have been missing for decades. This result suggests that somatosensory representations might rely more heavily on motor output than previously assumed. Robert Gaunt will present results from a human participant with abolished motor efference but essentially preserved somatosensory afference. This participant was trained to control an anthropomorphic robotic arm based on signals from M1. Gaunt and his collaborators compared conditions in which the person was provided proprioceptive input - by moving her native limb in conjunction with the prosthetic one - to conditions in which proprioceptive feedback was not available. Trials were also conducted with the subject's arm in a robotic exoskeleton controlled using decoded M1 signals. Strikingly, proprioceptive feedback modulated responses in M1, thereby directly demonstrating that proprioceptive input to M1 shapes its response properties. Collectively, these results hone in on the bidirectional interactions between somatosensory and motor cortices that play a critical role in motor control in the formation of sensory and motor representations in the brain.

Session 12, Panel VI

Friday, April 24 08:00 – 10:15

How the CNS Operates as a multi-user system

Jonathan Wolpaw[1], Andrea d'Avella[2], Aaron Batista[3], Aiko Thompson[4]

[1]Wadsworth Center (NY State Dept. of Health) and SUNY Albany, [2]Fondazione Santa Lucia, [3]University of Pittsburgh, [4]Medical University of South Carolina

The CNS is a multi-user system in which the users are all the skills that share its neurons and synapses. The entire CNS, from cortex to spinal cord, changes continually, as growth and aging occur, and as new skills are acquired. This ubiquitous plasticity raises a critical question: When acquisition of a new skill changes the CNS, how are old skills that use the same neurons and synapses preserved - why are old skills not disturbed by the plasticity that establishes a new skill? This panel will discuss the mechanisms that enable a continually changing CNS to acquire and maintain a reliable repertoire of skills. Wolpaw will consider the question for the spinal cord. He will review the 'negotiated equilibrium' hypothesis and the evidence for it provided by a simple model - operant conditioning of the H-reflex. When a new skill changes the spinal cord, old skills affected by the new plasticity induce compensatory plasticity. This in turn affects the new skill and other old skills, and leads to further plasticity. The result is an iterative process, or negotiation. The outcome is a new spinal cord equilibrium that serves the new skill and the old. d'Avella will consider the role of muscle synergies in the process by which the CNS acquires a new skill while preserving old skills. The acquisition of a skill that can be implemented by recombining existing synergies is likely to be faster than that of a skill that requires new or modified synergies. Evidence for faster synergy recombination processes comes from comparing adaptation to novel muscle-to-force mappings that are either compatible or incompatible with existing synergies. Batista will examine how the primary motor cortex (M1) acquires new skills and integrates them with old ones. Learning to control a brain-computer interface is a form of skill learning: it requires mapping neural activity patterns to cursor movement on a screen. We can predict the time needed to learn this mapping by how similar the new activity patterns are to the existing repertoire of patterns: if they are similar, they can be learned in a few hours; if they lie outside the space of existing patterns, learning may require a week or longer and may entail changes in existing patterns. Thompson will describe studies of skill acquisition in people with abnormal locomotion due to spinal cord injury or other CNS damage. A new skill that targets beneficial plasticity to an important pathway triggers a negotiation among skills that leads to widespread beneficial plasticity and improves locomotion. New motor-learning therapies designed to induce targeted plasticity can supplement other rehabilitation methods and enhance recovery. In sum, this panel will address the problem of motor learning as it is actually encountered by the CNS: it will discuss the processes that enable a system in which many skills share the same neural substrate to acquire new skills while maintaining previously acquired skills.

Session 13, Individual Presentations III

Friday, April 24 10:45 – 12:45

A large scale spiking model of the motor cortex and cerebellum in complex arm control

Travis DeWolf[1], Chris Eliasmith[1]

[1]University of Waterloo

Here we present a large-scale spiking neuron model of the pre-motor cortex, primary motor cortex, and cerebellum of the motor control system. The model consists of anatomically organized spiking neurons that control a non-linear three-link arm through several tasks. These tasks include standard centre-out reaching, learning to reach under the effects of a force-field, and drawing out words and numbers. The model is able to adapt to dynamical and kinematic changes in the system online, such as external forces or changing the length of the arm segments. The underlying dynamical system of the model is based on dynamic movement primitives (DMPs; Schaal et al, 2005), operational space control (Khatib, 1987), and nonlinear adaptive control (Slotine and Li, 1987; Cheah et al, 2005). The pre-motor cortex is modeled as a site responsible for trajectory generation, which we accomplish using DMPs. The primary motor cortex (M1) transforms the high-level control signals received from the pre-motor cortex (such as hand forces), and transforms them to low-level control signals that can be sent out to the arm (such as joint torques). M1 also adapts online to account for any changes in the kinematics (e.g. changes in the arm segment lengths), and generates a secondary control signal that works to keep the arm near resting state joint angles. The cerebellum generates corrective signals that cancel out any unwanted dynamics, using both internal models of the system's inertia as well as a high-speed adaptive signal. We use the methods of the Neural Engineering Framework (NEF; Eliasmith & Anderson, 2003) to implement these algorithms in a spiking neural network that consists of approximately 150,000 leaky-integrate and fire spiking neurons. We compare the model with clinical and experimental data, ranging from behavioural data, such as velocity profiles during reaching, to neural spiking data, such as movement parameter correlations and jPCA analysis (Churchland et al, 2012). We show that our model accounts for data from 19 clinical and experimental studies on the motor control system, and generates several novel, testable predictions. We believe that our model is unique in the breadth of behavioural and neural data that it accounts for.

Impact of muscle redundancy on the synergy hypothesis

Cristiano Alessandro[1], Robin Urselli[2], Juan Pablo Carbajal[3], Robert Riener[1]

[1]ETH Zürich, Sensory-Motor Systems Lab, [2]Politecnico di Milano, [3]Dwengo vzw

Over the last decades many experimental results have suggested that the central nervous system generates muscle commands by combining a small number of primitives, called muscle synergies (Alessandro et al., 2013). However, the theoretical foundations of the muscle synergy hypothesis are still under debate, and the influence of biomechanical factors on this hypothesis are largely unexplored. Recently we proposed a mathematical framework to analyze the concept of control modularity from a computational standpoint. In particular, we studied the problem of controlling a model of the human arm in accordance with the time-varying synergy formulation (d'Avella et al., 2003), i.e. restricting the admissible motor signals (i.e. torques) to linear combinations of fixed time-varying primitives (or synergies). This work allowed us to understand how many and which synergies are necessary to obtain satisfactory task performance (Alessandro et al., 2014). Results showed that reaching tasks can be executed satisfactorily by combining a small number of synergies, and suggested that these synergies represent motor programs associated to a set of representative tasks. Thereby, synergies embed information about the task and the system dynamics. What remained unclear from these investigations was whether the obtained results are valid for more realistic models of the human arm. Features like muscle redundancy and muscle dynamics were not included in the arm model, thus the impact of these biomechanical characteristics on the muscle synergy hypothesis could not be explored. In the present contribution we apply DRD to a model of the human arm controlled by forces applied to the links. Six forces map to 2 torques through a fixed lever arm, thus the system is input-redundant. An appropriate choice of the torque-to-force mapping (i.e. redundancy resolution) leads to results that are similar to those obtained in the model controlled by torques, using the same number of synergies. We therefore conclude that, under the given assumptions, input redundancy does not increase the dimensionality of control. This result is the consequence of the proper definition of the torque-to-force mapping. In general, the decomposition of a given torque into forces is not unique. The infinite number of force decompositions is due to the null-space of the lever arm matrix. Any given force decomposition can be shifted by an element of this null-space (null-space shift) without affecting the obtained torque. Theoretical and numerical observations suggest that, in order to obtain satisfactory task performance, it is enough to use a single null-space shift when decomposing any torque into forces. This preserves the properties of the desired force signals, which therefore can be approximated by a parsimonious set of force synergies. In summary, our work suggests that muscle redundancy, a fundamental biomechanical feature of the musculoskeletal system, does not affect control dimensionality.

How does the sensorimotor system represent a delayed velocity-dependent force field?

Guy Avraham[1], Firas Mawase[2], Lior Shmuelof[1], Opher Donchin[1], Ferdinando Mussa-Ivaldi[3], Ilana Nisky[1]

[1]Ben-Gurion University of the Negev, [2]Johns Hopkins University, [3]Northwestern University

Motor learning depends on effective control mechanisms that gather sensory feedback information from different modalities and enable accurate estimations and predictions of body state. Learning is achieved despite the different information transmission time that characterize each sensory modality. The representation of these time differences in the sensorimotor system is not fully understood. In prior studies, it was suggested that we cope with force perturbations while performing reaching movements by adjusting combinations of motor primitives that depend on state variables, such as position and velocity (Sing et al. 2009). It was also previously shown that participants are able to adapt to a delayed velocity-dependent force field, in which the applied lateral force at each time point within the movement is a linear function of the velocity a certain time beforehand (Levy et al. 2010). Here, we examine whether this adaptation depends on a representation of the delay and consequently, the use of delayed motor primitives, or whether the nervous system copes with such a perturbation using only non-delayed, state-based primitives. We exposed two groups of participants to either non-delayed or delayed velocity-dependent force perturbations and measured the lateral forces that they applied against the walls of a force-channel in a set of trials that were sparsely presented throughout the experiment. To assess the primitives that are required for adaptation, we fit a model to explain the forces that participants applied at the end of the adaptation session using various combinations of motor primitives (including: position, velocity, delayed-velocity and acceleration). We hypothesized that if participants from the delayed group use a time-based representation of the delay, after adaptation they will apply a force that is shifted in time with respect to the hand velocity, accordingly with the time lag presented in the perturbation. Alternatively, if such a representation of the delay is unavailable, the applied force will be a linear combination of non-delayed state-based primitives such as position, velocity, and acceleration. We show that participants from the non-delayed group apply forces that depend linearly on their current movement velocity. Interestingly, the delayed group's results suggest a force representation that can be best explained by a model which combines position, velocity and delayed velocity primitives. Thus, even though the perturbing force was a linear function of delayed velocity, participants continued to use non-delayed state-based primitives. However, some representation of the delay contributed to adaptation, as evident in the use of delayed velocity primitive. While we do not suggest a computational mechanism allowing the use of time-delayed primitives, our results suggest that our brain cannot build a full and reliable representation of an environment with time-delays, and has to rely also on non-delayed primitives.

Paradoxical benefits of dual-task contexts for visuomotor memory

Joo-Hyun Song[1], Hee Yeon Im[1], Patrick Bedard[1]

[1]Brown University

The marveling acts of Olympic gymnasts and stroke victims recovering the ability to walk both involve acquiring or reacquiring pertinent motor skills. Importantly, such adaptive motor skills are often used in new environments in which other stimuli or events compete for attentional resources. Attention is traditionally believed to facilitate many cognitive functions, including learning. However, previous studies have focused exclusively on immediate detrimental effects on motor performance, leaving the question of how divided attention affects memory formation or retrieval unanswered. Furthermore, attentional load can often change between learning a motor skill and subsequent recall and it is possible that such changes affect retention. Specifically, are motor skills learned free of distraction diminished at recall when distractions are present? Conversely, are motor skills learned when under distraction diminished at recall when there are no distractions? Using a dual- task paradigm pairing a visuomotor adaptation task with an attention-demanding secondary task, we examined how consistent attentional states across learning and recall affects different stages of visuomotor learning, including motor error reduction, memory formation, and recall. We showed that the rate of visuomotor learning was the same regardless of attentional distraction caused by a secondary task. Yet, when participants were tested later, a motor skill learned under distraction was remembered only when a similar distraction was present; when participants were tested without the distracting task, their performance reverted to untrained levels. This paradoxical result, in which the level of performance decreases when more attentional resources are available, suggests that the dual-task context, or the lack thereof, acts as a vital context for learning. This task-context-dependent "savings" was evident even when the specific secondary task or engaged sensory modality differed between learning and recall; thus, the dual-tasking, rather than the specific stimuli, provides context. Furthermore, we observed that this task-context-dependent modulation consistently manifested regardless of whether visuomotor adaptation was introduced abruptly (45°) or gradually in each trial (0.3° per trial). Thus, we suggest that feedback from the large reaching error during learning is not necessary for binding attentional states and visuomotor memory. In addition, we demonstrated that the dual-task state dependent modulation on visuomotor memory is a long-term effect, lasting over a day. Therefore, we argue that without consideration of internal task contexts in real-life situations, the success of learning and rehabilitation programs may be undermined. This new discovery of task-context-dependent memory indicates that visuomotor learning processes can be fully understood only by updating current models of attention, motor learning, and memory.

P3 or Not P3: Assessing the occurrence of the P300 event-related potential during sensorimotor memory updating during an object lifting task.

Kelene Fercho[1], Lee Baugh[1]

[1]University of South Dakota

Although our motor system is finely tuned to generate accurate movements when interacting with our environment, we inevitably make mistakes on a daily basis when manipulating our surroundings. The motor system is capable of adapting future movement based on the errors experienced in previous interactions with the world. A large component of this adaptive process is the updating of information within sensorimotor memory to allow for the efficient lifting of the newly encountered object in the future. To date, there is no optimal method for determining when sensorimotor memory is being updated in a real-time fashion. This study had thirteen participants perform an object lifting task in conjunction with EEG recording in order to assess whether the P300 event-related potential (ERP) was suitable as a biological marker to detect updating of the sensorimotor system. The P300 was chosen as it has long been theorized to relate to the brain activities involved in the updating of working memory in response to incoming stimuli. Participants lifted a series of blocks, a small percentage of which were inversely weighted (where the smaller block was heavier than the larger block). When lifting these infrequent inversely weighted blocks, sensorimotor memory updating should occur to facilitate future interactions with these objects that are not well represented by long-term motor priors. Offline analysis of lifting kinematics established that participants did require adjustments to their initial weight predictions when lifting the inversely weighted stimuli throughout the entire experiment. Importantly, as predicted, during those trials in which sensorimotor memory updating is thought to occur a significant effect in the amplitude of the P300 ERP was observed. Taken together, these results suggest that the P300 ERP may provide an adequate real-time biomarker of the updating of sensorimotor memory in an object lifting task.

Execution variability restricts locomotor adaptation in Cerebral Palsy patients

Firas Mawase[1], Simona Bar-Haim[2], Amir Karniel[2], Lior Shmuelof[2]

[1]Johns Hopkins University, [2]Ben-Gurion University

Cerebral Palsy (CP) results from an insult or an injury to the developing brain before birth or in early childhood and causes physical disability and atypical performance patterns. Furthermore, individuals with CP exhibit poor sensorimotor adaptation to changes in the environment and high variability in their performance. Bayesian inference theory suggests that variability and adaptation are related since high execution variability increases the uncertainty in the observations of the actor, and subsequently reduces the adaptation to the perceived errors. Thus, increased variability hardens the process of assigning the source of the observed error to extrinsic changes in the environment or to intrinsic source such as natural variability. Here, we used a multi-session adaptation design in CP and control patients that allow exploration of the interaction between adaptation patterns and execution variability. We hypothesized that poor sensorimotor adaptation in CP stems from a failure to assign the experienced errors to their external sources and not from a failure in the adaptation process itself. Nine diplegic CP adolescents were exposed to 30 sessions of split-belt treadmill adaptation spread over four consecutive months, and nine aged and gender matched healthy controls were exposed to comparable magnitude of perturbation spread over ten sessions of adaptation. Adaptation rates and execution variability were quantified by analyzing the asymmetry of the center of pressure and its variability across gate cycles. Compared to controls, CP patients showed, as expected, slower adaptation and higher execution variability in their first exposure to the perturbation. Following training, CP subjects showed a substantial increase in adaptation rates and a marked reduction in their execution variability. Furthermore, subjects retained the adapted patterns 6 months after training. We next tested our hypothesis using probabilistic (i.e. Bayesian framework) and deterministic (i.e. multiple rate state-space) learning models. In support of our claim, we found that the increase in adaptation rate can be explained by a reduction in observation noise, and that this improvement was associated with increased contribution of the fast learning process. Our finding suggest that prolonged training with the aim of reducing execution variability may improve the ability of CP subjects to adapt to environmental changes. Therefore, effective rehabilitation of CP patients should rely on two distinct interacting processes: shaping of motor patterns through adaptation together with reduction in variability through the process of tasks' repetition.

Session 15, Perspective II

Friday, April 24 14:45 – 16:15

New methods of analysis of population data- relating neural dynamics and Sherrington reductionism.

Simon Giszter[1], Terence Sanger[2], Maryam Shanechi[2],

John Cunningham[3]

[1]Drexel University, College of Medicine, [2]University of Southern California, [3]Columbia University

As new technologies rapidly develop , e.g., from the Brain Initiative, we can expect massively parallel neural recordings and optogenetic targeting routinely, and VR and BMI based augmentation, in complex experiments. Huge neural data sets resulting require new analysis techniques to extract the linkages to behavior, and ideally these should link to the intuitive physiology used to date in the motor system. Nonetheless, it is conceivable this is not possible. New analysis techniques may alter the nature of experimental designs and the descriptions to be used with them in radical ways. The goal of this panel is to explore this issue from three perspectives, and to consider the pros and cons and relations to classical circuit descriptions. Maryam M Shanechi, USC: We develop a novel closed-loop BMI architecture that allows arbitrarily fast control and feedback rates by employing two main components, a point process model of the spikes and an optimal feedback-control (OFC) model of the brain during neuroprosthetic control. The point process model relates the times-series of spikes to the intended control commands, which are predicted by the OFC model. An adaptive estimator is constructed to learn the point process model parameters. We show that this novel BMI architecture significantly outperforms state-of-the-art methods. Moreover, we use this architecture to identify the elements within the BMI system--feedback rate, control rate, and encoding model--that contribute to these improvements. Finally, we show how the novel point process BMI can dissect the contribution of different elements in the sensorimotor pathway, providing a unique tool for studying the mechanisms of natural and neuroprosthetic motor control. Terence D. Sanger, USC: Current methods for the analysis of i populations of spiking neurons have derived from studies of sensory systems, and reflect neurons whose responses are described by tuning curves. However, for understanding motor systems it is important that neurons with motor effects change the ongoing system dynamics, so that their behavior and importance is only partially described by their patterns of firing. The mathematical theory of Stochastic Dynamic Operators can be used to interpret the dynamic effects of populations of movement-related neurons, and to predict changed movement dynamics, functional stimulation effects, and injury effects. John P. Cunningham, Columbia University: Most motor functions depend on the interactions of many neurons. A key question is what scientific insight arises from studying populations of neurons beyond studying each neuron individually.We examine three important features of population studies: single-trial hypotheses requiring statistical power, hypotheses of population response structure and exploratory analyses of large data sets. Recent studies adopt dimensionality reduction for analysis of populations and to find features not seen at the level of individual neurons relations.

Session 16, Keynote

Friday, April 24 16:15 – 17:30

Old and New M1: A tale of two motor areas

Peter Strick[1]

[1] University of Pittsburgh

This presentation will lay out the evidence to develop the following thesis–

1. The central control of movement is faced with an evolutionary constraint: Our skeletomotor system is built on the framework of a relatively ancient spinal cord.
2. Most descending systems, including the corticospinal system, use the pattern generatorsand motor primitives that are built into the spinal cord to generate motor output.
3. Cortico-motoneuronal (CM) cells (i.e., cortical neurons with axons that make monosynaptic connections with motoneurons) are a relatively new phylogenetic and ontogenetic development. Furthermore, CM cells are located in a separate part of the primary motor cortex.
4. Thus, area 4 is split into 2 regions: a rostral region we have termed "Old M1" which has disynaptic input to motoneurons; and a caudal region we have termed "New M1" which has monosynaptic input to motoneurons.

In essence, Old M1 makes use of the circuits built into the spinal cord to generate motor output. This region of the motor cortex enables the motor system to avoid the "curse of dimensionality" and to solve the "degrees of freedom problem." In contrast, New M1 uses CM cells to bypass the constraints of spinal cord mechanisms. This region of the motor cortex enables the motor system to use all of the available degrees of freedom to sculpt novel patterns of motor output.

These arguments lead us to predict that the two regions of the motor cortex are differentially involved in motor learning. We speculate that Old M1 is especially important during the initial stages of learning a new skill by enabling the motor cortex to use existing spinal circuits to rapidly construct new movement patterns. In contrast, New M1 may be especially important during the later stages of learning a new skill by enabling the motor cortex to refine and precisely specify patterns of motor output.

NCM Society for the Neural Control of Movement

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1-C-12	Suarez-Escudero, D
1-C-13	Barrois, R
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1-D-2	Blum, K
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1-E-12	Lawrence, E
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1-F-8	Yokoi, A
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1-G-2	Gopal, A
1-G-3	Gremmler, S
1-G-4	Haji-Abolhassani, I
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Hours: Thursday, April 23 8:00 – 14:10
Friday, April 24 8:00 – 14:45

All posters listed below are part of Session 2. Locations of individual poster boards are indicated on the poster board floorplan inside the back cover of the program.

Poster board numbers work in the following way:
Poster Session – Theme – Poster Number within each theme (Example: 2-A-1)

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

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2-G-6	Panouillères, M
2-G-7	Phillips, C

Session 1

Tuesday, April 21 and Wednesday, April 22. Posters are listed by theme.

A - Adaptation & Plasticity in Motor Control

1-A-1 The intralimb stability of adaptation to novel movement dynamics is influenced by both the training schedule and the motion dependence of the perturbation
Laith Alhussein[1], Eghbal Hosseini[1], Katrina Nguyen[1], Wilsaan Joiner[1] [1]George Mason University

1-A-2 Explicit and implicit learning combine to support learning in visuomotor adaptation tasks
Krista Bond[1], Jordan Taylor[1] [1]Princeton University

1-A-3 An Examination of walking adaptation in healthy individuals when arm movements are perturbed
Yen-Wei Chen[1], Wen Ling[1], Smita Rao[1], Gregory Gutierrez[1]
[1]New York University

1-A-4 Remote limb ischemic conditioning enhances motor learning
Kendra Cherry-Allen[1], Jeff Gidday[1], Jin-Moo Lee[1], Tamara Hershey[1], Catherine Lang[1] [1]Washington University School of Medicine

1-A-5 Association between individuals' motor learning parameters across distinct adaptation tasks: visuomotor and force field comparisons.
Antonios Christou[1], Joseph Galea[1], Chris Miall[1]
[1]University of Birmingham

1-A-6 Visual gain reduces movement error by enhancing beta-band desynchronization in the sensorimotor cortex
Jae Woo Chung[1], Edward Ofori[1], David Vaillancourt[1]
[1]University of Florida

1-A-7 Functional connectivity underlying postural motor adaptation in people with multiple sclerosis
Brett Fling[1], Geetanjali Gera Dutta[1], Fay Horak[1]
[1]Oregon Health & Science University

1-A-8 Gait training through reinforcement
Christopher Hasson[1], Sheng-Che Yen[1] [1]Northeastern University

1-A-9 Dopaminergic contributions to vocal learning
Lukas Hoffmann[1], Varun Saravanan[1], Samuel Sober[1]
[1]Emory University

1-A-10 No effect of post-practice caffeine ingestion on 24-hour retention of a visuomotor skill
Sara Hussain[1], Kelly Cole[1] [1]University of Iowa

1-A-11 Investigating the neurobiological changes associated with cerebellar transcranial direct current stimulation (tDCS) using magnetic resonance imaging (MRI)
Roya Jalali[1], Ali Chowdhury[2], Martin Wilson[1], Stephen Mayhew[1], Chris Miall[1], Joseph Galea[1]
[1]UNIVERSITY OF BIRMINGHAM, [2]University Hospitals Birmingham NHS Foundation Trust

1-A-12 Different roles of primary motor cortex on intermanual transfer of CW/CCW force field adaptation
Shoko Kasuga[2], Hisashi Tajimi[3], Meigen Liu[1], Junichi Ushiba
[1]Keio University School of Medicine, [2]Faculty of Science and Technology, Keio University, [3]Graduate School of Science and Technology, Keio University, Keio University

1-A-13 Anodal motor cortex stimulation paired with movement repetition increases anterograde interference but not savings
Li-Ann Leow[1], Geoff Hammond[2], Aymar de Rugy[3]
[1]The University of Queensland, [2]The University of Western Australia, [3]CNRS UMR 5287, Universit e Bordeaux Segalen

1-A-14 Error-related modulation of the beta-rebound may reflect salience processing independent of sensorimotor adaptation.
Nicole Malfait[1], Flavie Torrecillos[2], Julie Alayrangues[2], Bjørg Kilavik[3], Nicole Malfait[3]
[1]CNRS / Institut de Neurosciences de la Timone, [2]Aix-Marseille University, [3]CNRS

1-A-15 Resting-state functional connectivity predicts observational motor learning
Heather McGregor[1], Paul Gribble[1] [1]Western University

1-A-16 The latency of visual feedback does not affect the learning of novel movement dynamics, but does influence fine movement accuracy
Erin McKenna[1], Laurence Bray[1], Wilsaan Joiner[1]
[1]George Mason University

1-A-17 Eccentric contractions impede the ability of the leg to regulate dynamic instabilities
Akira Nagamori[1], Emily Lawrence [1], James Finley[1], Francisco Valero-Cuevas [1] [1]University of Southern California

1-A-18 Modulation and fractionation of visuo-motor readiness in a competitive game
Ken Nakayama[1], Maryam Vaziri Pashkam[1], Marnix Naber[2]
[1]Harvard University, [2]Leiden University

1-A-19 Prism adaptation during reaching and walking: effects of task and aging on adaptation rate and after-effects
Samuel Nemanich[1], Gammon Earhart[1]
[1]Washington University in St. Louis

1-A-20 Role of contralateral anterior region of intraparietal sulcus in coordinating digit force to position for dexterous manipulation
Pranav Parikh[1], Marco Davare[2], Marco Santello[1]
[1]Arizona State University, [2]University College London

1-A-21 Subject-specific Adaptations in Muscle Synergies While Learning to Direct Pedal Forces
Sangsoo Park[1], Christopher Hasson[2], Graham Caldwell[1]
[1]University of Massachusetts Amherst, [2]Northeastern University

1-A-22 Increase of interhemispheric coherence during acquisition of asymmetric bimanual movements
Se-Woong Park[1], Courtney Stead[1], Dagmar Sternad[1]
[1]Northeastern University

1-A-23 Generalization of context-dependent motor memories: a mixed reference frame model
Luc Selen[1], Adjmal Sarwary[1]
[1]Donders Institute for Brain, Cognition and Behaviour

1-A-24 Practice-related improvements in visuospatial attention drive motor learning in a motor task requiring continuous and simultaneous perceptual, cognitive and motor processing.
Tarkeshwar Singh[1], Kayla Goins[1], Christopher Perry[1], Barbara Marebwa[1], Troy Herter[1] [1]University of South Carolina

1-A-25 Post-movement beta activities index confidence in the current internal model and are modulated by previous error history during visuomotor adaptation
Huiling Tan[1], Cian Wade[1], Peter Brown[1] [1]University of Oxford

B - Disorders of Motor Control

1-B-1 From horses to humans: Abnormal locomotor muscle recruitment patterns in horses with Purkinje cell axonopathy
Joshua Aman[1], Stephanie Valberg[1], Naveen Elangovan[1], Anibal Armien[1], Susannah Lewis[1], Jürgen Konczak[1]
[1]University of Minnesota

1-B-2 Multi motor unit activation, force control, and force dysmetria correlate with functional capacity in spinocerebellar ataxia 6
Evangelos Christou[1], Yen Ting Chen[1], Minhyuk Kwon[1], Agostina Moran[1], Amy Snyder[1], S. H. Subramony[1], David Vaillancourt[1]
[1]University of Florida

1-B-3 Visuomotor adaptation of the upper limb in presymptomatic and symptomatic patients with Spinocerebellar Ataxia Type 6
Muriel Panouillères[2], Raed Joundi[2], Sonia Benitez-Rivero[2], Binith Cheeran[2], Christopher Butler[2], Andrea Nemeth[2], Ned Jenkinson[2]
[1]University of Birmingham, [2]University of Oxford

1-B-4 Long-term motor learning improvements and transcranial direct current stimulation post stroke: A meta-analysis
Nyeonju Kang[1], Jeffery Summers[2], James Cauraugh[1]
[1]University of Florida, [2]University of Tasmania

1-B-5 Distinctive motor control strategies in Parkinson's disease during an unstable object manipulation and its implications to clinical evaluation
Na-hyeon Ko[1], Francisco Valero-Cuevas[1]
[1]University of Southern California

1-B-6 Task-dependent feedback control is impaired during Parkinson's disease
Isaac Kurtzer[1], Rosemary Gallagher[2]
[1]NYIT-College of Osteopathic Medicine, [2]NYIT

1-B-7 Reliability of the arm movement detection (AMD) test
Leigh Mrotek[1,2], Maria Bengtson[2], Christine Smith[2], Tina Stoeckmann[2], Claude Ghez[3], Robert Scheidt[2,4]
[1]UW-Oshkosh, [2]Marquette University, [3]Colombia University, [4]Northwestern University

1-B-8 Effects of carpal tunnel release surgery on recovery of sensorimotor hand function
Marco Santello[1], Mark Ross[2], Jan Light[2], Pranav Parikh[1]
[1]Arizona State University, [2]Mayo Clinic

1-B-9 Does language formulation benefit concurrent cycling in people with Parkinson's Disease?
Tiphanie Raffegeau[1], Lori Altmann[1], Elizabeth Stegemoller[2], Hyoken Lee[1], Chris Hass[1] [1]University of Florida, [2]Iowa State University

1-B-10 Robot-mediated mapping of reaching movement impairment of upper-limb hemiparetic stroke survivors
Orna Rosenthal[1], Alan Wing[1], Jeremy Wyatt [1], Chris Miall[1]
[1]University of Birmingham

1-B-11 Muscle coordination for feedback stabilization of arm posture after stroke
Robert Scheidt[1], Leigh Mrotek[2], Maria Bengtson[1], Tina Stoeckmann[1], Claude Ghez[3]
[1]Marquette University, [2]University of Wisconsin Oshkosh / Marquette University, [3]Columbia University Medical Schoo

1-B-12 Motor overflow in focal hand dystonia develops and perpetuates under correlated sensory inputs in neuromorphic simulation
Won Joon Sohn[1], Chuanxin Niu[2], Terence Sanger[1]
[1]University of Southern California, [2]Shanghai Jiao Tong University

C - Posture & Gait

1-C-1 Quantifying quiescent stance in secondary progressive multiple sclerosis with wireless inertial sensors
Brett Fling[1], Ishu Arpan[1], Jessie Huisinga[1], Fay Horak[1], Rebecca Spain[1]
[1]Oregon Health and Science University

1-C-2 The reliability and validity of the Zeno walkway system as a spatio-temporal measure of gait in healthy young adults.
Christian Hyde[1], Anna Murphy[2], Jennifer McGinley[3], Melissa Kirkovski[1], Jessica Batton[1], Peter Enticott[1]
[1]Deakin University, [2]Monash Health, [3]The University of Melbourne

1-C-3 muscular control of balance in a standing reaching task
Miriam Klous[1], Jennifer Hydrick[1] [1]College of Charleston

1-C-4 The effect of balance perturbations on cortical movement related oscillations during walking
Joseph Lee[1], Brian Schmit[1]
[1]Marquette University

1-C-5 Under-activation of neural circuits in OAs following postural perturbation: an ERP study.
C. Elaine Little[1], Marjorie Woollacott[2]
[1]University of Calgary, [2]University of Oregon

1-C-6 Combining Instructive and adaptive learning for teaching a new gait pattern
Andrew Long[1], Amy Bastian[1] [1]Johns Hopkins University

1-C-7 Modulation of spatiotemporal alpha motor neuron activity patterns during obstacle clearance in healthy adults
Michael MacLellan[1] [1]Louisiana State University

1-C-8 The critical phase for the visual control of foot placement when walking over complex terrain
Jonathan Matthis[1], Sean Barton[2], Brett Fajen[2]
[1]University of Texas at Austin, [2]Rensselaer Polytechnic Institute

1-C-9 Cat hindlimb muscle synergies during slope walking: Possible contributions of CPG and sensory feedback
Boris Prilutsky[1], Adil Akyildiz[1], Ricky Mehta[1], Alexander Klishko[1]
[1]Georgia Institute of Technology

1-C-10 Can Individuals with ACLR detect imposed asymmetry and symmetry during walking?
Jaimie Roper[1], Matthew Terza[1], Chris Hass[1] [1]University of Florida

1-C-11 Single step negotiation time differences in Parkinson's disease
Amanda Stone[1], Jared Skinner[1], Hyo Keun Lee[1], Chris Hass[1]
[1]University of Florida

1-C-12 Assessing gaze and motor control using Ambient Intelligence
Stephane Buffat[1], Daniel Suarez-Escudero[2], Emna Jelili[2], Christophe Labourdette[3], Pierre-Paul Vidal[2]
[1]IRBA, [2]UMR-MD Cognac G, [3]ENS Cachan

1-C-13 Quantifying head and trunk motion during locomotion measured with four accelerometers: a new detection method.
Rémi Barrois[1], Laurent Oudre[1], Thomas Moreau[1], Charles Truong[1], Catherine De Waele[1], Alain Yelnik[1], Thomas Gregory[2], Damien Ricard[3], Pierre-Paul Vidal[1]
[1]Université Paris Descartes - COGNAC G, [2]Hopital Européen Georges Pompidou - Service de chirurgie orthopédique, [3]HIA Val de Grace - service de neurologie

1-C-14 Changes in the structure of variability in kinematic data between normal treadmill and split-belt treadmill walking
Matthew Terza[1], Jaimie Roper[1], Chris Hass[1]
[1]University of Florida

D - Theoretical & Computational Motor Control

1-D-1 Quasi-static and smooth motions of tendon-driven limbs require non-smooth, highly posture-dependent, neural drive
Sarine Babikian[2], Eva Kanso[2], Francisco Valero-Cuevas[2]
[1]USC, [2]University of Southern California

1-D-2 Muscle spindles encode force information
Kyle Blum[1], Boris Lamotte d'Incamps[2], Daniel Zytnicki[2], Lena Ting[1]
[1]Georgia Tech and Emory University, [2]Université Paris Descartes

1-D-3 Vectormap: Visualization of the feasible force space to observe neuromuscular coordination constraints
Brian Cohn[1], Francisco Valero-Cuevas[1]
[1]University of Southern California

1-D-5 Identification of dynamic stiffness: From the ankle to a neuromorphic joint
Kian Jalaleddini[1], Victor Barradas[2], Chuanxin Niu[2], Robert Kearney[1], Francisco Valero-Cuevas[2]
[1]McGill Univerisity, [2]University of Southern California

1-D-6 On what basis does the brain select muscle activation patterns?
Dinant Kistemaker[1], Josh Cashaback[1], Heather McGregor[1], Paul Gribble[1]
[1]University of Western Ontario

1-D-7 Neuromotor noise can decrease with long-lasting persistence
Nikita Kuznetsov[1], Meghan Huber[1], Dagmar Sternad[1]
[1]Northeastern University

1-D-8 Muscle synergies for online simultaneous control of two degrees of freedom of a robotic arm
Francesca Lunardini[1], Claudia Casellato[1], Andrea d'Avella[2], Terence Sanger[3], Alessandra Pedrocchi[1]
[1]Politecnico di Milano, [2]Foundation Santa Lucia , [3]University of Southern California

1-D-9 A control model of human-dampening hand vibration using internal and external information
Shunta Togo[1], Takahiro Kagawa[2], Yoji Uno[2]
[1]Advanced Telecommunications Research Institute International, [2]Nagoya University

1-D-10 Error amplification improves performance by reducing motor noise
Zhaoran Zhang[1], Christopher Hasson[1], Masaki Abe[2], Dagmar Sternad[1]
[1]Northeastern University, [2]Hokkaido University

E - Fundamentals of Motor Control

1-E-1 The feedback response to error is a teaching signal during motor adaptation
Scott Albert[1], Reza Shadmehr[1]
[1]Johns Hopkins School of Medicine

1-E-2 Decoding directional selectivity in the human motor system from the dynamics of continuous tracking
Deborah Barany[1], Shivakumar Viswanathan[2], Matthew Cieslak[1], Eamon Caddigan[1], Scott Grafton[1]
[1]University of California, Santa Barbara, [2]Cologne University Hospital

1-E-3 Tactile gating: Noise filter or Input optimizer?
Gordon Binsted[1], Francisco Colino[1]
[1]University of British Columbia

1-E-4 Responses to startling acoustic stimuli indicate that movement-related activation is constant prior to action
Alexandra Leguerrier[1], Dana Maslovat[2], Ian Franks[2], Anthony Carlsen[1]
[1]University of Ottawa, [2]University of British Columbia

1-E-5 The acquisition and retention of a novel bimanual coordination pattern: A transcranial direct current stimulation investigation
Michael Carter[1], Dana Maslovat[2], Michelle Nguyen[1], Anthony Carlsen[1]
[1]University of Ottawa, [2]University of British Columbia

1-E-6 Startle reveals decreased preparatory-related activation during a stop-signal task compared to a simple reaction time task
Neil Drummond[1], Erin Cressman[1], Anthony Carlsen[1]
[1]University of Ottawa

1-E-7 Developmental improvements in motor planning are associated with an increased ability to engage the internal action representations across typical, but not atypical, motor development.
Ian Fuelscher[1], Jacqueline Williams[2], Peter Enticott[1], Christian Hyde[1]
[1]Deakin University, [2]Victoria University

1-E-8 Primary motor cortical neurons reflect vector sum of ipsilateral and contralateral feedback modulation
Ethan Heming[1], Stephen Scott[1]
[1]Queen's University

1-E-9 Involvement of the cerebellum and the posterior parietal cortex in state estimation
Angel Lago-Rodriguez[1], R. Chris Miall[1]
[1]University of Birmingham

1-E-10 Stability-dependent modulation of neural drive to the thumb during precision grip
Christopher Laine[1], Alexander Reyes[2], Francisco Valero-Cuevas[2], Dario Farina[1]
[1]Universitaetsmedizin Goettingen, [2]University of Southern California

1-E-11 Neural dynamics of self-initiated and quasi-automatic reaches
Antonio Lara[1], Mark Churchland[1]
[1]Columbia University

1-E-12 Sex differences in control strategies for both static and dynamic balance in young adults
Emily Lawrence[1], Guilherme Ceasar[1], Martha Bromfield[1], Richard Peterson[1], Susan Sigward[1], Francisco Valero-Cuevas[1]
[1]University of Southern California

1-E-13 Nonlinear dynamics coupling between emotion and motor performance
Hyo Keun Lee[1], Kyoungshin Park[1], Suk Hoon Yoon[2], Christopher Janelle[1], Chris Hass[1]
[1]University of Florida, [2]Korea National Sport University

1-E-14 Object manipulation is specific to the frame of reference in which it was learned
Michelle Marneweck[1], Lisa Knelange[2], Trevor Lee[1], Marco Santello[3], Andrew Gordon[1]
[1]Teachers College, Columbia University, [2]Vrije Universiteit Amsterdam, [3]Arizona State University

1-E-15 Projections from the cerebellar nuclei to the dorsal thalamus in a songbird, and their involvement with vocal motor control
David Nicholson[1], David Nicholson[1], Samuel Sober[1]
[1]Emory University

1-E-16 The inconvenient truth for motor control: Inability to voluntarily switch between motor programs leads to suboptimal motor behaviors
Jean-Jacques Orban de Xivry[1], Philippe Lefèvre[2]
[1]KU Leuven, [2]Université catholique de Louvain

1-E-17 Neural activity and learning in striatum during reaching movements
Barry Peterson[1]
[1]Northwestern University

1-E-18 Changes in corticomotoneuronal drive during stable and unstable object manipulation
Alexander Reyes[1], Jason Kutch[1], Francisco Valero-Cuevas[1]
[1]University of Southern California

1-E-19 Quickly making the correct choice
Jeroen Smeets[1], Eli Brenner[1]
[1]VU University Amsterdam

1-E-20 Preferred discharge of identified soleus motor units in response to tendon vibration in the decerebrate cat
Christopher Thompson[1], Michael Johnson[1], Francesco Negro[2], Matthew Holmes[1], Dario Farina[2], CJ Heckman[1]
[1]Northwestern University, [2]Georg-August University

1-E-21 Sensory prediction during different phases of observed actions modulates tactile processing
Roberta Vastano[1], Alberto Inuggi[1], Marco Jacono[1], Thierry Pozzo[1]
[1]Italian Institute of technology

1-E-22 Planning movement trajectories in extrinsic space: moving beyond the point-to-point reach
Aaron Wong[1], Jeff Goldsmith[2], John Krakauer[1]
[1]Johns Hopkins University School of Medicine, [2]Columbia Mailman School of Public Health

F - Integrative Control of Movement

1-F-1 Coordinated feedback control of of upper-limb and hand muscles during object manipulation tasks
Frederic Crevecoeur[1], Jean-Louis Thonnard[1], Stephen Scott[2], Philippe Lefevre[1]
[1]Université catholique de Louvain, [2]Queen's University

1-F-2 Movement preparation and execution in the mouse motor cortex during a novel head-fixed sensorimotor discrimination task
Jeffrey Dahlen[1], EunJung Hwang[1], Takaki Komiyama[1]
[1]University of California San Diego

1-F-3 Comparison of functional properties of neurons in the dorsal premotor cortex and the superior colliculus during reaching in macaque monkeys
Klaus-Peter Hoffmann[1], Ramakrishnan Sureshbabu[1], Claudia Distler[1]
[1]Ruhr University Bochum

1-F-4 Observing surgeon behavior in robot-assisted surgery: what can we learn?
Anthony Jarc[1], Ilana Nisky[2]
[1]Intuitive Surgical, Inc., [2]Ben Gurion University of the Negev

1-F-5 Temporal evolution of theta and beta band activities during motor preparation reveals the reach endpoint formation process in a free pointing task
Dan Li[1], Claudio Campus[1], Alberto Inuggi[1], Thierry Pozzo[1]
[1]Istituto Italiano Di Tecnologia

1-F-6 The role of anticipation in the size-weight illusion
Myrthe Plaisier[1], Jeroen Smeets[1]
[1]VU University

1-F-7 Dynamic regional perturbation of reaching against gravity in healthy young and older individuals
George Wittenberg[1], Jing Tian[1], Nick Kortzorg[2], Lore Wyers[2], Stephan Swinnen[2], Oron Levin[2], Ilse Jonkers[2]
[1]Dept. of Veterans Affairs / University of Maryland, [2]KU Leuven

1-F-8 Hierarchical representation of motor sequence revealed by representational similarity analysis on human fMRI data
Atsushi Yokoi[1], Uri Hertz[1], Elizabeth Bamber[2], Joern Diedrichsen[1]
[1]Institute of Cognitive Neuroscience, University College London, [2]Unversity of Cambridge

G - Control of Eye & Head Movement

1-G-1 Effects of anterior cingulate cortex deactivation on dorsolateral prefrontal cortex local field potential activity and the control of task switching
Jason Chan[1], Kevin Johnston[1], Stephen Lomber[1], Stefan Everling[1]
[1]University of Western Ontario

1-G-2 Computational mechanisms for eye hand control
Atul Gopal[1]; Aditya Murthy[2]
[1]National Brain Research Center, [2]Indian Institute of Science

1-G-3 Saccadic adaptation is associated with starting eye position
Svenja Gremmler[1], Markus Lappe[1]
[1]University of Muenster

1-G-4 Segment-filtering: optimal filtering of short-duration segments
Iman Haji-Abolhassani[1], Henrietta Galiana[1]
[1]McGill University

1-G-5 Size matters for eyes and hand: saccadic adaptation and changes to manual object size estimation
Markus Lappe[1], Annalisa Bosco[2], Patrizia Fattori[2]
[1]University of Muenster, [2]University of Bologna

1-G-6 Vestibular compensation in unilateral patients often causes both gain and time constant (dynamics) asymmetries in the VOR
Henrietta Galiana[1], Mina Ranjbaran Hesarmaskan[1]
[1]McGill University

1-G-7 Modulation of vigor during a temporal discounting task
Thomas Reppert[1], Karolina Lempert[2], Paul Glimcher[2], Reza Shadmehr[1]
[1]Johns Hopkins University, [2]New York University

Session 2

Thursday, April 23 and Friday, April 24.

Posters are listed by theme.

A - Adaptation & Plasticity in Motor Control

2-A-1 The neural correlates of the slow and fast processes of motor adaptation

Simone Brownless[1], Briony Brownless[1], Paul Pope[1], Chris Miall[1]
[1]The University of Birmingham

2-A-2 Older adults can transfer error detection ability from ankle to elbow

Yen-Ting Chen[1], Agostina Casamento Moran[1], Minhyuk Kwon[1], Evangelos Christou[1]
[1]University of Florida

2-A-3 The effects of long duration bed rest as a spaceflight analogue on resting state sensorimotor network functional connectivity and neurocognitive performance

Kaitlin Cassady[1], Vincent Koppelmans[1], Peng Yuan[1], Katherine Cooke[1], Yiri De Dios[2], Vahagn Stepanyan[2], Darcy Szecsy[3], Nichole Gadd[2], Scott Wood[4], Patricia Reuter-Lorenz[1], Roy Riascos Castenada[5], Igor Kofman[2], Jacob Bloomberg[6], Ajitkumar Mulavara[6]
[1]University of Michigan - Ann Arbor, [2]Wyle Science, Technology, and Engineering Group, [3]Bastion Technologies, [4]Azusa Pacific University, [5]University of Texas Health Science Center, [6]NASA Johnson Space Center

2-A-4 Robust and model-based control capture differences in motor learning strategies

Tyler Cluff[1], Frédéric Crevecoeur[2], Stephen Scott[1]
[1]Queen's University, [2]Université Catholique de Louvain

2-A-5 Mouse locomotor adaptation on a split-belt treadmill

Dana Darmohray[1], Megan Carey[1]
[1]Champalimaud Centre for the Unknown

2-A-6 Transfer of tactile perceptual learning to untrained neighbouring fingers reflects natural use relationships

Harriet Dempsey-Jones[1], Harriet Dempsey-Jones[1], Vanessa Harrar[2], Jonathan Oliver[1], Heidi Johansen-Berg[1], Charles Spence[1], Tamar Makin[1]
[1]Oxford University, [2]University of Montreal

2-A-7 People with Multiple Sclerosis have preserved capacity for postural motor learning

Geetanjali Dutta[1], Brett Fling[2], Fay Horak[2]
[1]Oregon Health Sciences University, [2]Oregon Health & Science University

2-A-8 Asymmetric learning in an asymmetric bimanual task

Julia Ebert[1], Se-Woong Park[1], Dagmar Sternad[1]
[1]Northeastern University

2-A-9 Proprioceptive function improves with robotic visuo-motor training in healthy adults

Naveen Elangovan[1], Joshua Aman[1], Juergen Konczak[1]
[1]University of Minnesota

2-A-10 Coordinated modulation of dynamic stability and metabolic cost during split-belt adaptation

James Finley[1], Sung-woo Park[1]
[1]University of Southern California

2-A-11 Transcranial direct current stimulation during a prism adaptation task

Brittany Gluskin[1], Brian Greeley[1], Rachael Seidler[1]
[1]University of Michigan

2-A-12 Transcranial direct current stimulation over primary motor cortex increases explicit awareness, but not performance, of an implicit sequence

Brian Greeley[1], Brittany Gluskin[1], Rachael Seidler[1]
[1]University of Michigan

2-A-13 The relationship between task specificity and training duration for a novel video gaming skill

David Huberdeau[1], Adrian Haith[1], Kat McNally[1], Promit Roy[1], Omar Ahmad[1], John Krakauer[1]
[1]Johns Hopkins University

2-A-14 Interference in discrete bimanual movements after gradual perturbation of one hand

Florian Kagerer[1]
[1]Michigan State University

2-A-15 7T fMRI reveals preserved SI topography of phantom fingers decades post amputation

Sanne Kikkert[1], James Kolasinski[1], Saad Jbabdi[1], Irene Tracey[1], Christian Beckmann[2], Heidi Johansen-Berg [1], Tamar Makin[1]
[1]University of Oxford, [2]Radboud University

2-A-16 Aging increases visual information processing time resulting in slower response time with altered activation of motor neuron pool

MinHyuk Kwon[1], Yen-Ting Chen[1], Abby Garner[1], Danielle Solis[1], Forrest Rackard[1], Virginia Pedigo[1], Bianca Dancose-Giambattisto [1], Christopher Sue-Wah-Sing [1], Evangelos Christou[1]
[1]University of Florida

2-A-17 Intrinsic biases systematically affect visuomotor adaptation experiments

Ryan Morehead[1], Richard Ivry[1]
[1]University of California, Berkeley

2-A-18 Trial-by-trial motor adaptation in hand and joint spaces with a multi-joint exoskeleton robot

Youngmin Oh[1], Giovanni Sutanto[1], Michael Mistry[2], Stefan Schaal[1], Nicolas Schweighofer[1]
[1]University of Southern California, [2]University of Birmingham

2-A-19 Differential resting-state functional connectivity in cerebellar patients and healthy controls accompany changes in motor adaptation to a visuomotor rotation.

Paul Pope[1], Roxana Burciu[2], Nina Theysohn[3], Chris Miall[1], Dagmar Timmann-Braun[3]
[1]University of Birmingham, [2]University of Florida, [3]University of Duisburg-Essen

2-A-20 Neural basis for motor learning: Reward anticipatory activity in sensorimotor cortical areas

Arjun Ramakrishnan[1], Kyle Rand[2], Mikhail Lebedev[2], Miguel Nicolelis[2]
[1]Duke University, [2]Duke University Medical Center

2-A-21 Motor generalization and interference in dominant and non-dominant hand

Adjmal Sarwary[1], Luc Selen[1], Dick Stegeman[1], Pieter Medendorp[1]
[1]Donders Institute

2-A-22 Modulation of hand impedance to manipulate fragile, trembling objects
Atsushi Takagi[1], Samuel Maxwell[1], Etienne Burdet[1]
[1]Imperial College London

2-A-23 Linking actions and objects: context-specific learning of novel weight priors
Kevin Trewartha[1], J. Randall Flanagan[1]
[1]Queens University

2-A-24 Influence of perspective of action observation training on motor outcomes in naïve prosthesis usage
Lewis Wheaton[1], Lewis Wheaton[1], Delisa Lawson[1], Regan Lawson[1], Ashley Hardy[1], Robert Kistenberg[1], William Cusack[1]
[1]Georgia Tech

2-A-25 Increased brain activation for foot movement during 70-day 6° head-down bed rest (HDBR): evidence from functional magnetic resonance imaging (fMRI)
Peng Yuan[1], Vincent Koppelmans[1], Kaitlin Cassady[1], Katherine Cooke[1], Yiri De Dios[2], Vahagn Stepanyan[2], Darcy Szecsy[3], Nichole Gadd[2], Scott Wood[4], Patricia Reuter-Lorenz[1], Roy Riascos-Castaneda[5], Igor Kofman[2], Jacob Bloomberg[6], Ajitkumar Mulava
[1]University of Michigan, [2]Wyle Science, Technology & Engineering Group, [3]Barrios Technologies, [4]Azusa Pacific University, [5]The University of Texas Health Science Center, [6]NASA Johnson Space Center, [7]NASA Johnson Space Center, Universities Space Research A

2-A-26 Is visuomotor memory represented according to gaze-referenced coordinates, or as a gain field combination of intrinsic and extrinsic representations?
Kim Aske[1], Dominic Farris[1], Aymar de Rugy[2], Timothy Carroll[1]
[1]The University of Queensland, [2]Institut de Neurosciences Cognitives et Intégratives d'Aquitaine

2-A-27 Distinct coordinate systems for adaptations of movement direction and extent
Eugene Poh[1], Timothy Carroll[1], Aymar de Rugy[2]
[1]The University of Queensland, [2]Université de Bordeaux

B - Disorders of Motor Control

2-B-1 Fluctuation analysis of eye movements in essential tremor
John Anderson[1], Jeffrey Willging[2]
[1]Minneaplis VA Health Care System - University of Minnesota, [2]University of Minnesota

2-B-2 Manipulation of visual stimulus characteristics on postural control of dyslexic children
Jose Barela[1], Milena Razuk[2]
[1]Cruzeiro do Sul University, [2]University of Cruzeiro do Sul

2-b-3 dystonic children can learn: Improving sensorimotor performance with solutions that are tolerant to variability
Virginia Way Tong Chu[1]
[1]University of Illinois at Chicago

2-B-4 Linear transmission of tremor synaptic inputs to motoneurons in Parkinson's disease
Juan Alvaro Gallego[1], Jakob Dideriksen[2], Ales Holobar[3], Jose Pons[4], Eduardo Rocon[4], Dario Farina[5]
[1]Northwestern University, [2]Aalborg University, [3]University of Maribor, [4]Spanish National Research Council (CSIC), [5]Georg-August University

2-B-5 Sensorimotor networks during fine motor control become more lateralized in chronic stroke subjects
Benjamin Kalinosky[1], Brian Schmit[1]
[1]Marquette University

2-B-6 Myoelectric activity encodes rehabilitative motor learning for individuals with spinal cord injury in a reaching task
General Lee[1] [1]Walter Reed Army Institute of Research

2-B-7 Reactive driving performace following stroke
Neha Lodha[1], Evangelos Christou[1]
[1]University of Florida

2-B-8 What is the basis for cerebellar deficits in proprioception?
Heidi Weeks[2], Amy Bastian[2]
[1]Johns Hopkins University, [2]Johns Hopkins University School of Medicine

2-B-9 Motor unit firing properties of the triceps brachii in mild-moderate Parkinson's disease
Jessica Wilson[1], Christopher Thompson[1], CJ Heckman[1]
[1]Northwestern University

2-B-10 Sensorimotor beta-band oscillations reveal no special benefit from rhythmicity in Parkinson's disease
Erik te Woerd[1], Robert Oostenveld[2], Bastiaan Bloem[1], Floris de Lange[2], Peter Praamstra[1]
[1]Radboud University Medical Centre, [2]Donders Institute for Brain, Cognition and Behaviour

2-B-11 Changes in neural activity patterns during recovery of hand function
Jörn Diedrichsen[2], Jing Xu[1], Naveed Ejaz[1], Benjamin Hertler[3], Meret Branscheidt[3], Mario Widmer[3], Nathan Kim[2], Michelle Harran[4], Juan Cortes[4], Tomoko Kitago[4], Pablo Celnik[2]
University College London[1], Johns Hopkins University[2], University of Zurich[3], Columbia University[4]

C - Posture & Gait

2-C-1 Recruiting common muscle synergies across balance and walking may be associated with better walking performance post-stroke
Jessica Allen[1], Lena Ting[1]
[1]Emory University and Georgia Tech

2-C-2 The Gait Variability Index, a new composite measure of gait variability, decreases with aging
Chitra Balasubramanian[1], Arnaud Gouelle[2]
[1]University of North Florida, [2]Plateforme d'Analyse du Mouvement

2-C-3 Gait training of individuals with chronic stroke using partial body weight support on a treadmill versus over the ground
Ana Barela[1], Gabriela Gama[1], Melissa Celestino[1], Dinah Santana[1], Jose Barela[1]
[1]Cruzeiro do Sul University

2-C-4 Tuning of postural responses to instability and cost function
Matteo Bertucco[1], Amber Dunning[1], Terence Sanger[1]
[1]University of Southern California

2-C-5 Evaluation of a phantogram groundplane for the study of visually guided walking behavior
Gabriel Diaz[1], Kamran Binaee[1], Andrew Smith[1], Rahul Gopinathan[1]
[1]The Rochester Institute of Technology

2-C-6 Anterior lean positions facilitate the displacement and velocity of center of pressure during forward gait initiation
Bradley Fawver[1], Carolina Sarmento[1], Christopher Hass[1]
[1]University of Florida

2-C-7 From humans to robots and back: Role of arm movement in medio-lateral balance control
Meghan Huber[1], Enrico Chiovetto[2], Ludovic Righetti[3], Stefan Schaal[3], Martin Giese[2], Dagmar Sternad[1]
[1]Northeastern University, [2]University Clinic Tübingen, [3]Max Planck Institute for Intelligent Systems

2-C-8 The LocoMouse system provides a quantitative framework for whole-body coordination and reveals specific deficits in freely walking ataxic mice
Ana Machado[2], Dana Darmoharay[2], Joao Fayad[2], Hugo Marques[2], Megan Carey[2]
[1]Champalimaud Neuroscience Program, [2]Champalimaud Centre for the Unknown

2-C-9 Expertise in balance is mediated by a set of shared muscle synergies that generalize across motor behaviors
Andrew Sawers[1], Lena Ting[1]
[1]Emory University and Georgia Institute of Technology

2-C-10 Short-latency crossed responses in the human biceps femoris muscle
Andrew Stevenson[1], Ernest Kamavuako[1], Svend Geertsen[2], Thomas Sinkjær[3], Dario Farina[4], Natalie Mrachacz-Kersting[1]
[1]Aalborg University, [2]University of Copenhagen, [3]Danish National Research Foundation, [4]Georg-August University

2-C-12 Pilates exercise improves static and dynamic balance following stroke
Sukhoon Yoon[1], Christopher Janelle[2], Chris Hass[2]
[1]Korea National Sport University, [2]University of Florida

D - Theoretical & Computational Motor Control

2-D-1 Reward feedback increases reaching vigor
Alaa Ahmed[1], Reza Shadmehr[1], Ali Nikooyan[1]
[1]University of Colorado

2-D-2 Modeling endpoint forces of the upper arm post-stroke
Helen Bacon[1], Andrew Hooyman[1], K. Michael Rowley[1], Francisco Valero-Cuevas[1]
[1]University of Southern California

2-D-4 Modular motor control in full-body, goal-directed movements
Leif Johnson[1], Dana Ballard[1]
[1]The University of Texas at Austin

2-D-5 Movement duration and effort determine arm choice
Sujin Kim[1], Hyeshin Park[1], Cheol Han[2], Carolee Winstein[1], Nicolas Schweighofer[1]
[1]University of Southern California, [2]Korea University

2-D-6 Assessment of error in motion reconstruction at low frame rates
Lijia Liu[1], Leif Johnson[1], Dana Ballard[1]
[1]University of Texas at Austin

2-D-7 Explicit aiming strategies and implicit forward model adaptation underlie the fast and slow components of motor learning.
Samuel McDougle[1], Jordan Taylor[1]
[1]Princeton University

2-D-8 Only suboptimal muscle activation patterns for muscle synergies generalize motor function across postures
M. Hongchul Sohn[1], Lena Ting[2]
[1]Georgia Institute of Technology, [2]Emory University

2-D-9 Motor equivalence in speech motor control: The "Uncontrolled Manifold" approach
Andrew Szabados[1], Pascal Perrier[2]
[1]University of Grenoble, [2]Grenoble-INP

2-D-10 A dynamical model of peripheral fatigue
Madhusudhan Venkadesan[1], Somya Mani[2]
[1]Yale University, [2]National Centre for Biological Sciences

E - Fundamentals of Motor Control

2-E-1 Deficit In motor inhibitory mechanisms in detoxified alcohol-dependent patients
Caroline Quoilin[1], Emmanuelle Wilhelm[1], Philippe de Timary[1], Pierre Maurage[1], Julie Duqué[1]
[1]Université catholique de Louvain

2-E-2 A TMS method for assessing inhibition for impulse control and competition resolution simultaneously during hand selection
Emmanuelle Wilhelm[1], Julie Duque[1]
[1]Université catholique Louvain

2-E-3 Contribution of primary motor cortex to perceptual and value-based decision processes
Gerard Derosiere[1], Alexandre Zenon[1], Andrea Alamia[1], Pierre-Alexandre Klein[1], Julie Duque[1]
[1]Institute of Neuroscience, Catholic University of Louvain

2-E-4 Bimanual motor synergies and nonlinear analyses reveal visual gain benefits for bimanual force control
James Cauraugh[1], Nyeonju Kang[1], Amitoj Bhullar[1]
[1]University of Florida

2-E-5 An Optogenetic demonstration of motor primitives in the mouse spinal cord
Vincent Chi Kwan Cheung[1], Vittorio Caggiano[2], Emilio Bizzi[3]
[1]The Chinese University of Hong Kong, [2]Karolinska Institute, [3]MIT

2-E-6 Inter-hemispheric interaction is the bases for the Goldilocks principle of motor learning: A postulate
Alexandra Court[1], Samantha Stevenson[1], Kalpish Shah[1], Nathan Vassey[1], Robert Kohl[1]
[1]College of William and Mary

2-E-7 The tuning of reflexes to environmental risk
Amber Dunning[1], Matteo Bertucco[1], Terence Sanger[1]
[1]University of Southern California

2-E-8 Functional interaction between monkey premotor and posterior parietal cortex for goal-directed behavior
Alexander Gail[1], Pablo Martinez-Vazquez[1], Steffanie Westendorff[1], Christian Klaes[1]
[1]German Primate Center

2-E-9 Acquisition of a novel visuomotor map alters online movement correction and trial-by-trial adaptation
Takuji Hayashi[1], Atsushi Yokoi[2], Masaya Hirashima[3], Daichi Nozaki[1]
[1]The University of Tokyo, [2]Institute of Cognitive Neuroscience, University College London, [3]Center for Information and Neural Networks, National Institute of Information & Communications Tec

2-E-10 Utilizing CN VII to negotiate intention in motor control and learning
Robert Kohl[1], Nathan Vassey[1], Samantha Stevenson[1], Kalpish Shah[1], Alexandra Court[1]
[1]The College of Williama & Mary

2-E-11 Bilateral force deficit is induced in bimanual common-goal but not dual-goal tasks and related to intracortical inhibition.
Wan-wen Liao[1], Jill Whitall[1], Joseph Barton[1], Sandra McCombe-Waller[1]
[1]University of Maryland Baltimore

2-E-12 Training and movement frequency affect paraspinal muscle activation patterns in cyclic segmental spine motions
Marilee Nugent[1], Theodore Milner[1]
[1]McGill University

2-E-13 Timing of cerebellar signals: from now to know
Laurentiu Popa[1], Martha Streng[1], Timothy Ebner[1]
[1]University of Minnesota

2-E-14 Planning a switch between simple and complex movements: No evidence for intermediate trajectories
Nicola Popp[1], Aaron Wong[1], John Krakauer[1]
[1]Johns Hopkins University School of Medicine

2-E-15 Influence of visual and motor aspects of target separation on sensorimotor oscillatory activity; a visuomotor adaptation study
Peter Praamstra[1], Tineke Grent-'t-Jong[1], Robert Oostenveld[2], Ole Jensen[2], W. Pieter Medendorp[2]
[1]Radboud University Medical Centre, [2]Radboud University Nijmegen, Donders Institute for Brain, Cognition, and Behaviour

2-E-16 Corticospinal excitability during co-contraction is further reduced by baroreceptor unloading with orthostatic stress
Minoru Shinohara[1], Vasiliy Buharin[2]
[1]Georgia Institute of Technology, [2]Boston Scientific

2-E-17 Human arms remove energy for increased stability during partnered stepping tasks with a robot follower
Yun Seong Song[1], Tiffany Chen[1], Tapomayukh Bhattacharjee[1], J. Lucas McKay[2], Madeleine Hackney[3], Charlie Kemp[1], Lena Ting[2]
[1]Georgia Institute of Technology, [2]Emory University, [3]Department of Veterans Affairs Medical Center

2-E-18 Manipulations of visual feedback modulate Purkinje cell encoding of task performance consistent with a forward internal model
Martha Streng[1], Laurentiu Popa[1], Timothy Ebner[1]
[1]University of Minnesota

2-E-19 Towards measurement and understanding of human impedance control during voluntary impacts
Naohiro Takemura[1], Toshinori Yoshioka[2], Tsuyoshi Ikegami[1], Daniela Korhammer[6], Hannes Hoeppner[3], Patrick van der Smagt[4,5], Ganesh Gowrishankar[1]
[1]Center for Information and Neural Networks, National Institute of Information and Communications Technology , [2]Advanced Telecommunications Research Institution International, [3]Institute for Robotics and Mechatronics, German Aerospace Center DLR, [4]Machine Learning Department, [5]BRML Labs, [6]Lehrstuhl fur Echtzeitsysteme und Robotik, Fakultät für Informatik, Technische Universität München

2-E-20 Continuous limb stiffness evaluation
Patrick van der Smagt[1], Daniela Korhammer[1], Naohiro Takemura[2], Hannes Hoeppner[3], Ganesh Gowrishankar[4]
[1]Technische Universität München, [2]National Institute of Information and Communications Technology, [3]German Aerospace Center / DLR, [4]National Institute of Advanced Industrial Science and Technology (AIST)

2-E-21 Two hemispheres are better than one for motor learning
Nathan Vassey[1], Kalpish Shah[1], Samantha Stevenson[1], Alexandra Court[1], Robert Kohl[1]
[1]The College of William and Mary

2-E-22 Goal-dependent modulation of the long-latency stretch response at the shoulder, elbow and wrist muscles
Jeff Weiler[1], Paul Gribble[1], Andrew Pruszynski[1]
[1]University of Western Ontario

2-E-23 Error direction, but not magnitude, is critical for motor adaptation
Peter Butcher[1], Jordan Taylor[1]
[1]Princeton University

F - Integrative Control of Movement

2-F-1 Modulation of correlated neural oscillations in motor cortex and muscle due to afferent input and co-contraction
Ellenor Brown[1], Jun Ueda[1], Minoru Shinohara[1]
[1]Georgia Institute of Technology

2-F-2 Online control as a singular multisensory process?
John de Grosbois[1], Rachel Goodman[1], Luc Tremblay[1]
[1]University of Toronto

2-F-3 Influence of movement contingencies on competing actions in reaching decisions
Vincent Enachescu[1]
[1]University of Southern California

2-F-4 Developing an assessment task for measuring dynamic upper limb proprioceptive acuity in an ageing population
Nick Kitchen[1]
[1]University of Birmingham

2-F-5 I spy with my dominant eye: The critical role of visual information from the dominant eye for online upper limb control
Tristan Loria[1], Damian Manzone[1], Valentin Crainic[1], Luc Tremblay[1]
[1]University of Toronto

2-F-6 Speech movement planning modulates auditory processing in typical speakers but not individuals who stutter
Ludo Max[1], Ayoub Daliri[2]
[1]University of Washington, [2]Boston University

2-F-7 Redundant levels of modular motor control revealed by peripheral sensory loss

Aiden Payne[1], Andrew Sawers[1], Jessica Allen[1], Jane Macpherson[2], Lena Ting[1]
[1]Georgia Institute of Technology and Emory University, [2]Oregon Health and Science University

2-F-8 Predictive timing in lateral cerebellum during a countermanding task

Vincent Prevosto[1], Marc Sommer[1]
[1]Duke University

2-F-9 Directional acuity of whole-body perturbations during standing balance

Melissa Puntkattalee[1], Clarissa Whitmire[1], Garrett Stanley[1], Lena Ting[1]
[1]Georgia Institute of Technology and Emory University

G - Control of Eye & Head Movement

2-G-1 Evolution of a reference frame along a brain pathway: persistently hybrid coordinates of auditory signals in Frontal Eye Fields implicate the Superior Colliculus in computing eye-centered sound location

Valeria Caruso[1], Daniel Pages[1], Marc Sommer[1], Jennifer Groh[1]
[1]Duke University

2-G-2 Eye-Hand coordination when manipulating non-rigid objects

Frederic Danion[1], Caroline Landelle[2], Anna Montagnini[2], Laurent Perrinet[2], Laurent Madelain[3]
[1]CNRS & Aix-Marseille University, [2]Aix-Marseille University CNRS, [3]Lille University CNRS

2-G-3 Eye movement-related modulation of the auditory transduction apparatus as recorded with a microphone in the external ear canal

Kurtis Gruters[1], Christopher Shera[2], Jennifer Groh[1]
[1]Duke University, [2]Harvard Medical School Massachusetts Eye & Ear Infirmary

2-G-4 Fitts' Theorem in Oculomotor control: Pro and antisaccades are not characterized by a unitary relation between movement time and index of difficulty

Matthew Heath[1], Ashna Samani[1], Jeffrey Weiler[1], Luc Tremblay[2]
[1]University of Western Ontario, [2]University of Toronto

2-G-5 Low-frequency oscillations in force and muscle activity relate to force variability during sinusoidal tasks

Changki Kim[1], Seoung Hoon Park[1], Cecilia Paez[1], Hwasil Moon[1], Evangelos Christou[1]
[1]University of Florida

2-G-6 Distinct properties of short-term and long-term saccadic adaptation in human

Muriel Panouillères[1], Daniel Drew[1], Chris Miall[2], Ned Jenkinson[1]
[1]University of Oxford, [2]University of Birmingham

2-G-7 Activity of secondary vestibular neurons during prosthetic vestibular stimulation

James Phillips[1], Christopher Phillips[1], Leo Ling[1], Kaibao Nie[1], Amy Nowack[1], Jay Rubinstein[1], James Phillips[1]
[1]University of Washington

Notes

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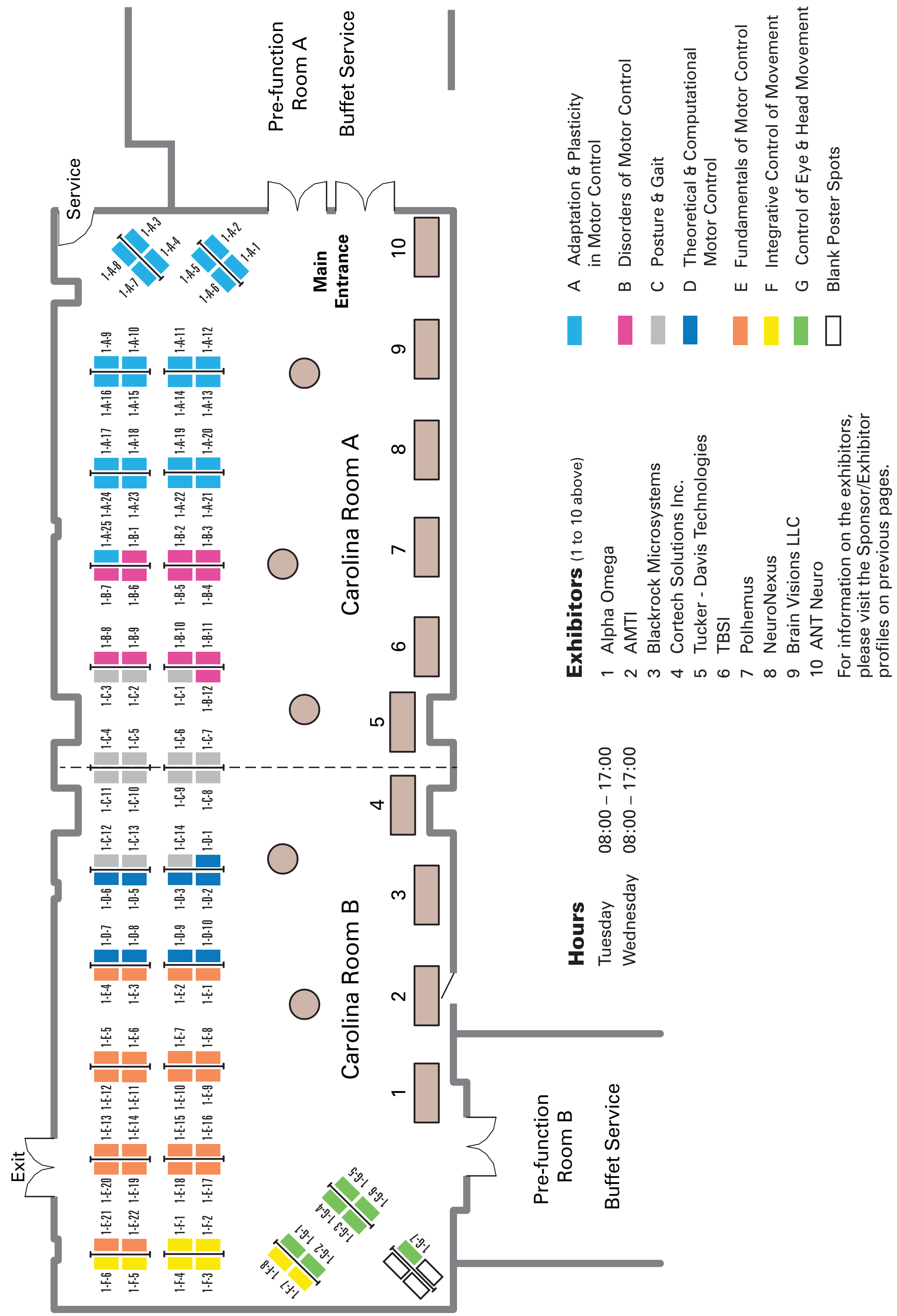
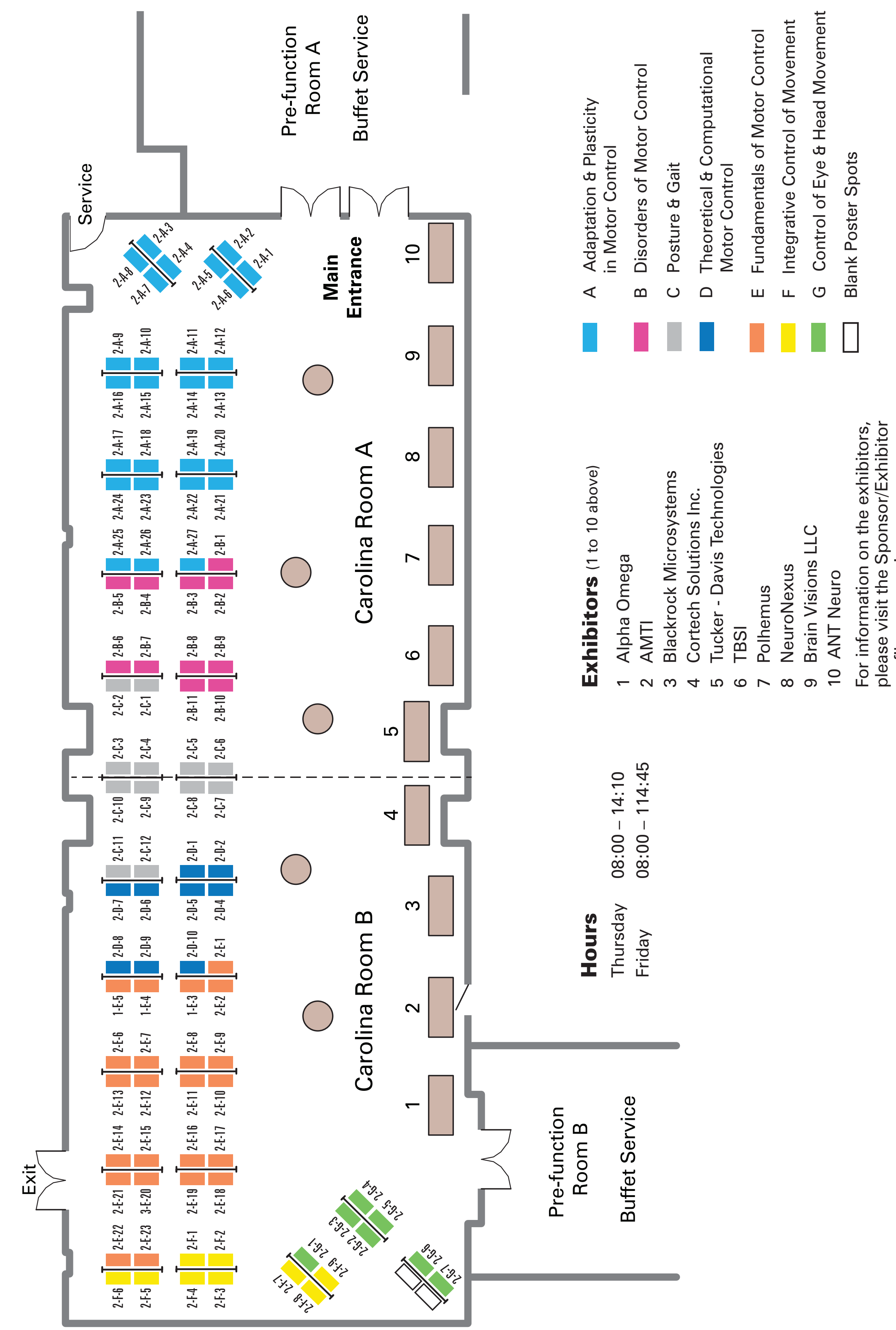
Tuesday, April 21 and Wednesday, April 22 • Carolina Ballroom A & B



Poster Session 2 Floor Plan

Thursday, April 23 and Friday, April 24 • Carolina Ballroom A & B



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