28th Annual Meeting

Society for the Neural Control of Movement

NCM

Santa Fe, New Mexico

Hilton Santa Fe Buffalo Thunder

Satellite Meeting
April 30, 2018

Annual Meeting
May 1–4, 2018

www.ncm-society.org • #NCMSaFe

2018 At-A-Glance Satellite and Annual Meeting Schedule

Hilton Santa Fe Buffalo Thunder

Society for the **Neural Control of Movement**

NCM

Time	Sunday 29-Apr	Monday 30-Apr	Tuesday 01-May	Wednesday 02-May	Thursday 03-May	Friday 04-May
8:00	Arrivals, Free Time	Registration /Information Desk Open Satellite Meeting	Registration / Information Desk Open Posters on Display (Session 1) Exhibits on Display ***Session 1 Panel I*** *Chakrabarti (08:00 - 10:15)*	Registration / Information Desk Open Posters on Display (Session 1) Exhibits on Display ***Session 5 Panel III*** *Makin* (8:00 - 10:15)	Registration / Information Desk Open Posters on Display (Session 2) Exhibits on Display ***Session 9 Panel V*** *Ostry* (08:00 - 10:15)	Registration / Information Desk Open Posters on Display (Session 2) ***Session 12 Panel VI*** *Sohn* (08:00 - 10:15)
8:15						
8:30						
8:45						
9:00						
9:15						
9:30						
9:45						
10:00						
10:15			**Break** (10:15 - 10:45)	**Break** (10:15 - 10:45)	**Break** (10:15 - 10:45)	**Break** (10:15 - 10:45)
10:30						
10:45			***Session 2 Panel II*** *Torres-Oviedo* (10:45 - 13:00)	***Session 6 Panel IV*** *Ting* (10:45 - 13:00)	***Early Career Talk*** Andrew Pruszynski	***Session 13 Individual III*** (10:45 - 12:45)
11:00						
11:15					***Session 10 Perspective I*** *Buneo* (11:15 - 12:45)	
11:30						
11:45						
12:00						
12:15						
12:30						
12:45					***Session 11*** **Poster 2a Lunch** (12:45 - 14:45)	***Session 14*** **Poster 2b Lunch** (12:45 - 14:45)
13:00			***Session 3*** **Poster 1a Lunch** (13:00 - 15:00)	***Session 7*** **Poster 1b Lunch** (13:00 - 15:00)		
13:15						
13:30						
13:45						
14:00						
14:15						
14:30						
14:45					**Free Time and/or Excursions**	***Session 15 Panel VII*** *Hortobagyi* (14:45 - 16:45)
15:00			***Session 4 Individual I*** (15:00 - 17:00)	***Session 8 Individual II*** (15:00 - 16:40)		
15:15						
15:30						
15:45						
16:00						
16:15						
16:30						
16:45				**Members' Meeting** (16:45 - 17:15)		***Session 16*** **Keynote Speaker** Ann Graybiel (16:45 - 18:00)
17:00	Satellite Registration **Satellite Registration** (17:00 - 19:00)		**Free Time**			
17:15				**Free Time**		
17:30			**NCM Board Meeting** (17:30 - 20:30)			
17:45						
18:00	**Satellite Drinks Reception** Jernez Terrace (18:00 - 19:00)					**Closing Drinks Reception Pueblo 3** (18:00 - 19:00)
18:15						
18:30						
18:45						
19:00						
19:15						**Free Time**
19:30		**Opening Reception Red Sage & Pool Patio** (19:30 - 21:30)	**Fire Side Chats** Red Sage Patio	**Fire Side Chats** Red Sage Patio	**NCM Pub Night** The Draft Station in Santa Fe	
19:45						
20:00						
20:15						
20:30						
20:45						
21:00						
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22:00						
22:15						
22:30						

Program Contents

About NCM

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

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

From the outset the goal of NCM was to provide a useful gathering of investigators in an informal and casual setting to present and discuss where we are in a diverse and complex field, where we should be going and how we might best proceed as a community with multiple perspectives and approaches. The meeting was to be unique in style, such that sessions were formulated and proposed by small groups of members, each and geared to inform the larger attending community through focused presentations and discussions integrated into themes reflecting the diversity of the membership. 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) 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. Sessions have expanded to include a variety of formats and durations to accommodate diverse needs and interests, while poster sessions have been augmented to yield highly popular, vibrant and flexible forums of scientific interchange. This highly regarded and robust conference continues to meet in desirable, family-friendly locations typically in late April/early May every year.

Welcome

To the Society for the Neural Control of Movement 28th Annual Meeting

Welcome to the 28th annual meeting of the Society for the Neural Control of Movement in the shadow of the picturesque Sangre de Cristo Mountains of Santa Fe! NCM has undertaken a variety of new initiatives this past year. In an exciting first for the society, we have received support for the meeting though an R13 award from NIH. We are particularly delighted that, in addition to the primary funding through the National Institute of Neurological Disorders and Stroke, additional funding has been provided by no fewer than four other national institutes: Child Health & Human Development, Biomedical Imaging & Bioengineering, Aging, and the Eye Institute. Special thanks to Daofen Chen, NINDS program director, who encouraged our application and has been a loyal NCM member for many years.

Lee Miller, President

We built the NIH application to increase diversity – in gender, national origin, and programming. We have formalized new submission policies to assure appropriate gender balance in programming, with funds given to some speakers who would not otherwise attend the meeting. The NIH award also includes funds to launch an NCM Minorities Fellowship Program and to reduce rates both for registrants from the developing world and faculty from primarily undergraduate institutions. The board initiated a reduced rate for post-doctoral fellows, in part covered by the grant. Rachael Seidler, NCM secretary/treasurer, will administer the Minorities Fellowship Program and other diversity initiatives.

This year, 15 post-doctoral and student trainees received travel awards, awards previously underwritten solely through income from exhibitors and other advertisers. To sponsor a larger, more consistent number of trainees, the board will now supplement this travel budget each year. An additional perk for these trainees is the opportunity to write a meeting review article, to be published this year in the Journal of Neurophysiology; six award winners have volunteered to contribute to that effort. Brian Corneil's role as NCM development officer has been expanded to include this and a range of other outreach projects directed at student and post-doctoral members.

NCM welcomes Adrian Haith of Johns Hopkins University, who was elected to a first term on the board. Alaa Ahmed, Scott Grafton, and Dagmar Sternad were reelected to second terms. As you may know, board elections are held in early spring, following nomination of a slate of candidates. Do take advantage of the opportunity to nominate someone next spring who would serve the Society well. In that vein, plan to attend the members' meeting at the end of the final session on Wednesday. In addition to giving the annual report and highlighting future meeting locations, we will discuss a new NCM code of conduct under consideration by the board–an important topic inviting all members' thoughtful discussion.

Since 2009, the annual meeting has culminated in a keynote address from a distinguished senior investigator. This year's senior keynote address, "Shining Light in the Dark Basement: The Basal Ganglia in Action," will be delivered by Ann Graybiel, Institute Professor and a faculty member in the Department of Brain and Cognitive Sciences at the Massachusetts Institute of Technology. Beginning this year, the senior keynote speaker will be joined by an Early Career Award Winner, who will deliver a keynote talk earlier in the week. Andrew Pruszynski, assistant professor in Physiology and Pharmacology at Western University, inaugural winner of this award, will address "Somatosensory Feedback for Real-world Hand Control."

We are fortunate this year to be able to draw on local expertise at the Santa Fe Institute for an exciting satellite preceding the main meeting. SFI is an independent research center that studies complex systems science and runs educational and outreach programs. Joined by select NCM discussants, SFI will conduct a one-day workshop entitled "The Complexity of the Nervous System."

Though Santa Fe doesn't boast quite as many pubs as our 2017 Dublin venue, the Buffalo Thunder resort does offer great outdoor patios complete with fire pits. With a nod to 32ND U.S. President FDR, we've swapped pub crawls for fire-side chats. Plan to spend some time around the fire each evening, discussing your latest experiments or your favorite and least favorite heads of state. For those who really need a pub, never fear, The Draft Station is offering 15% off food and $1 off pints to badge-wearing neuroscientists on Thursday night, May 3.

As always, I am grateful for all the behind-the-scenes work by Marischal De Armond and Podium Conference Specialists who made these chats, the pub deal, and the rest of the meeting possible. Share a s'more with one of them to say thank you!

Cordially,

Lee Miller, 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:

Society for the Neural Control of Movement
NCM

Kathleen Cullen

Brian Corneil

Rachael Seidler

Officers (Executive Committee)

President & Conference Chair
Lee Miller

Vice President & Scientific Chair
Kathleen Cullen

Treasurer & Secretary
Rachael Seidler

Development Officer
Brian Corneil

Board Members

Name	Institution	Country	Term
Alaa Ahmed[1]	University Colorado	USA	2015 – 2018
Scott Grafton[1]	UCSB	USA	2015 – 2018
Dagmar Sternad[1]	Northeastern University	USA	2015 – 2018
Andrew Pruszynski[2]	University of Western Ontario	Canada	2015 – 2018
Pieter Medendorp[1]	Donders Institute for Brain, Cognition and Behaviour	Netherlands	2016 – 2019
Lena Ting[2]	Emory University	USA	2016 – 2019
John van Opstal[2]	Donders Institute	Netherlands	2016 – 2019
Max Berniker[1]	University of Illinois at Chicago	USA	2017 – 2020
Florian Kagerer[1]	Michigan State University	USA	2017 – 2020
Jean-Jacques Orban de Xivry[2]	Catholic University of Louvain	Belgium	2017 – 2020
Gelsy Torres[1]	University of Pittsburgh	USA	2017 – 2020

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

Incoming Board Members

The following members will begin serving their term at the close of the 2018 Annual Meeting:

Alaa Ahmed[2]	University Colorado	USA
Scott Grafton[2]	University of California, Santa Barbara	USA
Adrian Haith[1]	Johns Hopkins University	USA
Dagmar Sternad[2]	Northeastern University	USA

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 NCM's Board members or Officers, or send an email to Treasurer@NCM-Society.org.

NCM Administration

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

Podium Conference Specialists
Michelle Smith
Marischal De Armond
Laurie De Armond

General Meeting Information

Meeting Venue

Hilton Santa Fe Buffalo Thunder

20 Buffalo Thunder Trail, Santa Fe, NM 87506 USA

Check in: 16:00 Check out: 12:00

All conference sessions will take place in this location.

The Opening Reception will be on site in the Red Sage and Pool Patio.

Registration

Satellite Meeting

Satellite Meeting registration fees include a complimentary drink during a drop in gathering on Sunday April 29, access to the full day meeting with refreshment breaks and a buffet lunch on Monday April 30.

Annual Conference

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 at The Red Sage Restaurant and Pool Patio 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 and excursions. 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, and receptions. Please wear it at all times. At the end of the Conference we ask that you recycle your name badge in one of the name badge recycling stations that will be set out, or leave it at the Registration Desk.

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

Dress Code

Dress is casual for all NCM meetings and social events.

Registration and Information Desk Hours

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

Sunday, April 29	17:00 – 19:00
Monday, April 30	08:00 – 19:00
Tuesday, May 1	07:30 – 15:00
Wednesday, May 2	07:30 – 16:45
Thursday, May 3	07:30 – 14:45
Friday, May 4	07:30 – 17:00

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

Staff

NCM staff from Podium Conference Specialists can be identified by orange 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.

Internet Services

Wireless Internet is available to Annual Meeting delegates for no charge. Simply choose the **Hilton Santa Fe Meeting or HSF2.4GHZ network and enter the password NCM18**. Kindly note, the WiFi strength is ideal for checking emails and websites but is not strong enough for streaming videos or heavy social media use.

If you are active on social media, make sure to hashtag #NCMSaFe @ncm_soc when referring to the meeting. We ask all NCM delegates to respect no live tweeting of presentations without prior approval from the speakers/authors and no photography in the poster hall. We encourage social tweets about the conference and look forward to growing our online community.

If you require assistance, please visit the registration desk and we will endeavour to assist you.

Bedrooms booked through NCM's group room block includes complimentary wireless internet on the Hilton Honors or ATT network in the guest room.

Poster Information

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, May 1, 07:00 and 10:00

Remove: Wednesday, May 2, between 17:00 and 18:00

Poster Session 2

Set-up: Thursday, May 3, between 07:00 and 10:00

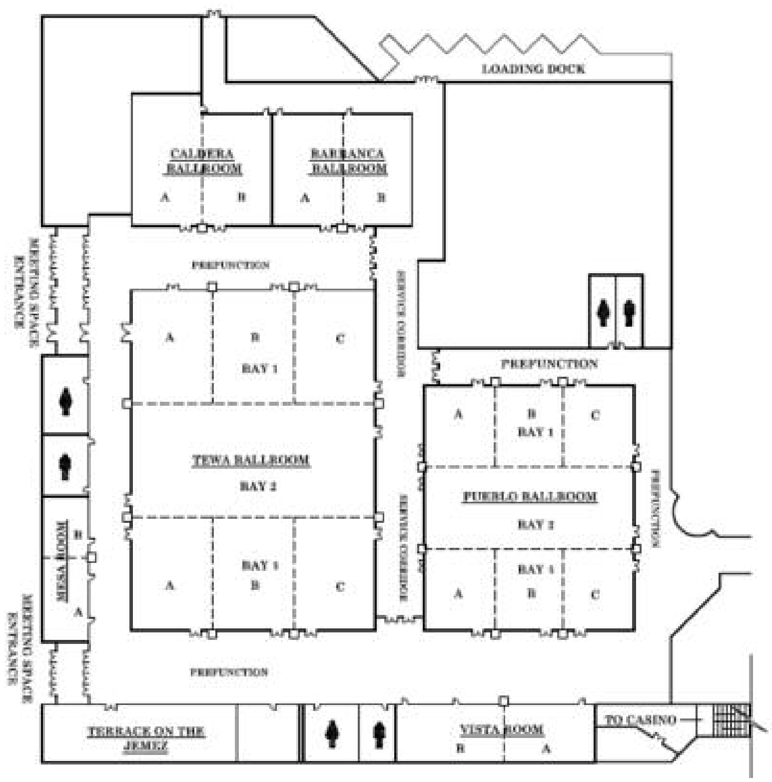
Remove: Friday, May 4, immediately following the end of the poster session.

Any posters that are not taken down by the removal deadline will be held at the registration desk until the end of the Meeting. Any posters that remain unclaimed by the end of the Meeting will be disposed of. Information on poster authors, poster numbers and poster titles begins on page 34. For a complete copy of all the poster abstracts, a digital abstract booklet 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.

Meeting Venue Floor Plan

No Smoking Policy
The Hilton Santa Fe Buffalo Thunder is a completely non-smoking facility. Smoking areas are located outside the front entrance to the hotel.



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
27th Annual Meeting*	May 1 – 5, 2017	Dublin	Ireland	Clayton Hotel, Burlington Road
26th Annual Meeting*	April 24 – 29, 2016	Montego Bay	Jamaica	Hilton Rose Hall Resort
25th Annual Meeting*	April 20 – 24, 2015	Charleston, SC	USA	Francis Marion 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

NCM Membership Information

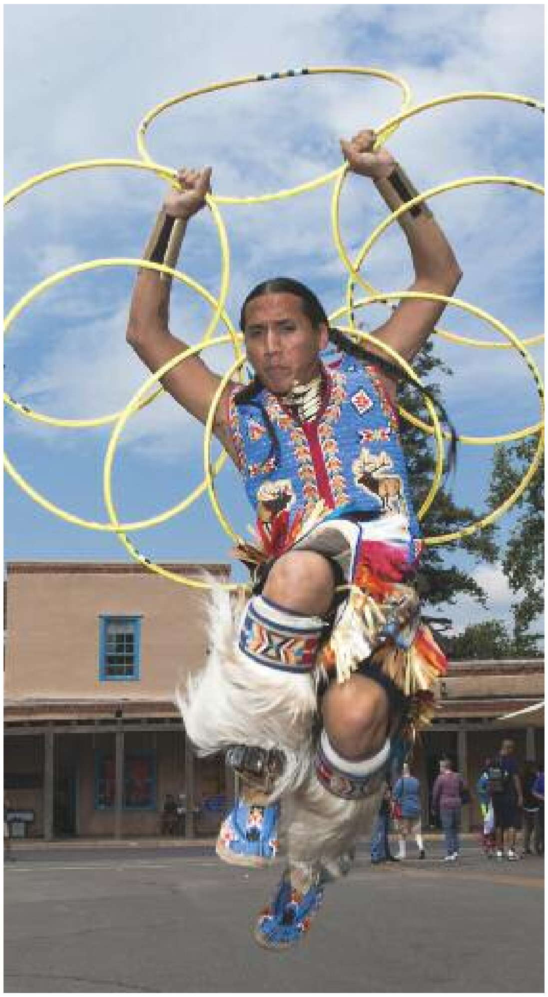
NCM membership is open to all scientists, principal investigators and students from around the world, pursuing research whose goal is to understand how the brain controls movement. Memberships are valid September 1 through August 31 each year.

NCM membership includes the following benefits:

- Opportunity to submit proposals and abstracts for sessions at the Annual 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
- Access and ability to respond directly to job opportunity postings
- Ability to post job opportunities
- 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.

Special Meetings & Events



Sunday, April 29
18:00 – 19:00

Satellite Drinks Reception
(Satellite Meeting Registrants)
Jemez Terrace

Monday, April 30
19:30 – 21:30

Opening Reception
Join us for an evening to catch up with old friends, meet new acquaintances and enjoy the Santa Fe evening under the Sangre de Cristo Mountains. A unique performance of traditional **Hoop Dancing** will occur at 20:00 by the local youth from the Pueblo.

Red Sage and Pool Patio

Fire Side Chats
Join us on the **Red Sage Patio** around the fire pits to discuss the day after 19:30, Tuesday and Wednesday nights.

Wednesday, May 2
16:45 – 17:15

NCM Members Meeting
Tewa Ballroom

Thursday May 3
19:30 – Last Call

Draft Station
60 E San Francisco Street

Join us following dinner in downtown Santa Fe to catch up on the day, experience New Mexico's best craft breweries, and enjoy the sights and sound of this bustling city.

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$1.00 off pints and 15% off food for delegates who show their NCM Namebadge.

Friday, May 4
18:00 – 19:00

Closing Drinks Reception
Pueblo 3

Annual Meeting Code of Conduct

The Society for the Neural Control of Movement (NCM) encourages open and honest intellectual debate within a welcoming and inclusive atmosphere at the Annual Meeting and through official NCM social media channels. To help maintain an open and respectful community of scientists, NCM does not tolerate illegal or inappropriate behavior at any annual meeting, including violations of applicable laws of the country in which the meeting is taking place. NCM condemns inappropriate or suggestive acts or comments that demean or harass another person by reason of gender, gender identity or expression, sexual orientation, physical appearance, ethnicity/race, religion (or lack thereof), or that are generally unwelcome or offensive to other members of the community. Sexual language and imagery, unless related to specific scientific discussions, is not appropriate for any conference venue, including talks, workshops, parties, Twitter and other online media. As the NCM Annual Meeting is attended by a wide spectrum of delegates, please be aware of the power dynamic between PIs, post doctoral fellows and students and how that dynamic may affect interactions amongst delegates.

By registering for the NCM Annual Meeting and/or Satellite Meeting, all delegates understand and agree to abide by the Code of Conduct as stated above.

NCM Society for the Neural Control of Movement

Conference Excursions

Tsankawi Ruins at Bandelier National Monument

Thursday May 3, 2018   3 pm – 7 pm

Price: $130 per person (includes transportation)

Pick up Hilton Santa Fe Buffalo Thunder: 3:00pm

Arrival at Tsankawi at 3:30pm

Return to the Hilton at 7:00pm

Part of Bandelier National Monument, Tsankawi is located on a mesa with amazing views of the surrounding mountains. Tsankawi has numerous cave dwellings with remarkable petroglyphs along the cliff walls. The trails here are more rugged than at the main park – you'll walk along ancient footpaths without rail guards and concrete steps. For the adventurous hikers, there are options to explore beyond the mesa loop, off the beaten path to secluded caves and rarely seen petroglyphs.

Please note that although portions of the area are an easy walk, there are some ladders and ancient steps to navigate.

Tour the Santa Fe Institute (SFI)

Thursday May 3, 2018   3:30pm – 4:45pm

Arrival at Santa Fe Institute: 3:30pm

Departure from Santa Fe Institute: 4:45pm

SANTA FE INSTITUTE

This tour will allow participants to tour the Cowan campus of the Santa Fe Institute and provide an overview of the scientific and educational activities that occur at the institute. Please note that very limited space is available for this tour and is not expected to increase.

Transportation is not provided and must be arranged separately.

NCM Satellite Meeting Detailed Daily Program

Santa Fe, New Mexico • April 29 & 30, 2018

All sessions will be held at the Hilton Santa Fe Buffalo Thunder Hotel

The Complexity of the Nervous System

The science of complexity is fundamentally concerned with the study of many-body adaptive systems – for example, an ant colony or a country's economy.

The brain is arguably the ultimate complex adaptive system, as it is made up of millions of individual entities (neurons) that interact across multiple spatial and temporal timescales in order to learn about the body and the environment.

Beginning in the last third of the twentieth century, frameworks have begun to emerge that seek to explain the behavior of aggregated learning systems like the brain. These include network theory, scaling laws, and non-linear dynamics. The Santa Fe Institute is at the center of these theoretical efforts.

In this one-day satellite session, we shall review recent progress in complexity science. Introducing the fundamental tools and concepts required to understand adaptive neural phenomena. Our goal is to candidly demonstrate what they can and what they cannot do. We shall illustrate their power to make sense of complicated data as applied to neural case studios.

Sunday, April 29

17:00 – 19:00 Satellite Registration

18:00 – 19:00 Satellite Drinks Reception, Jemez Terrace

The satellite symposium is organized by the Santa Fe Institute.

SANTA FE INSTITUTE

Monday, April 30

08:00 – 08:30 Registration

08:30 – 09:30 **Introduction to complex systems – the science of networks of adaptive agents**

David Krakauer, Santa Fe Institute

What is complexity and why does it need a new science? I shall introduce the fundamental challenge of complex systems, the methods that are emerging to address the challenge, and some recent frameworks and theories of complexity. The brain is a complex system that has often been treated as if it were a simple system with a single optimal level of analysis. What might complexity neuroscience look like?

09:30 – 09:45 Coffee Break

09:45 – 12:00 **Machine learning, "deep neural networks", and the brain**

Artemy Kolchinsky, Santa Fe Institute

In recent times, so-called "deep neural networks" have led to a revolution in machine learning, delivering unprecedented performance on a wide variety of difficult tasks. This tutorial will discuss the fundamentals of machine learning, how and why deep neural networks work, and what machine learning and neuroscience can tell each other.

12:00 – 13:00 Lunch

13:00 – 14:00 **Criticality and robustness in networks of neurons**

Michelle Girvan, Santa Fe Institute and University of Maryland

Experimental evidence suggests that networks of neurons operate near a critical point, i.e., the boundary between an order-disorder phase transition. Criticality provides the order needed for coherent function while at the same time allowing the system the flexibility that is associated with the disordered state. Mathematical models of phase transitions in neuronal networks help us to identify features of the brain's wiring that are key for optimal information processing.

14:00 – 15:00 **Why we sleep; Unravelling neural reorganization from repair**

Geoffrey West, Santa Fe Institute

A mechanistic framework for why we sleep and for understanding and predicting quantitatively how sleep changes across organisms and as individuals grow will be presented. Combined with a comprehensive analysis of human sleep data for total sleep time, REM sleep, cerebral metabolic rate, brain size, and synaptic density the theory shows how this can distinguish between sleep used for neural reorganization versus repair and how these change during ontogeny, including how they relate to REM and non-REM sleep. A dramatic transition is revealed at 2.4 years old in humans akin to the phase transition as when water freezes to ice.

15:00 – 15:30 Coffee Break

15:30 – 16:30 **Towards principles of collective computation for adaptive systems**

Jessica Flack, Santa Fe Institute

I will introduce a framework for studying how adaptive systems, from brains to societies to ai, accumulate & integrate information during collective computation, given noisy data, processing constraints, a finite population of imperfect sensors, and in the absence of a clear termination criterion. I will then illustrate the potential power of this framework to a) facilitate explicit comparison across these (seemingly very different) systems by guiding question choice and experimental design, and b) identify general computational principles.

16:30 – 17:30 **Panel – Questions and General Discussion**

David Krakauer, Artemy Kolchinsky, Michelle Girvan, Geoffrey West, Jessica Flack, and NCM Discussants

19:30 – 21:30 **Opening Reception for Annual Meeting**

Please Note: If you registered to attend the Satellite Meeting ONLY and want to attend the dinner, tickets can be purchased at the registration desk.

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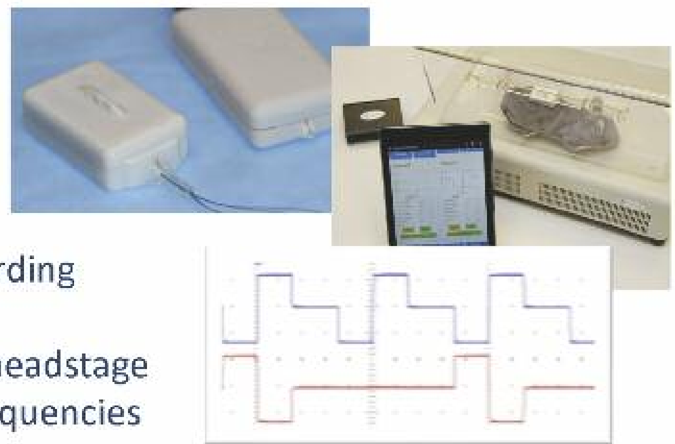

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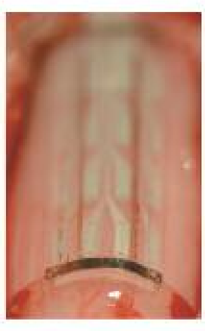

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NCM Annual Meeting Detailed Daily Program

April 30 – May 4, 2018 • Santa Fe, New Mexico

All sessions will be held at the Hilton Santa Fe Buffalo Thunder
Posters and Exhibits will be located in the Tewa Ballroom

DAY 1 Monday, April 30

19:30 – 21:30 **Opening Drinks Reception**

DAY 2 Tuesday, May 1

08:00 – 10:15 **Session 1, Panel I**

Sensory gating – origins, mechanisms, functions
Organizer: Shubo Chakrabarti • Participants: Kazuhiko Seki, Kathleen Cullen, James Kilner

10:15 – 10:45 Break

10:45 – 13:00 **Session 2, Panel II**

The role of practice in motor learning: from sensorimotor adaptation to mastering de-novo skills
Organizer: Gelsy Torres-Oviedo • Participants: Adrian Haith, Virginia Penhune, Steven Chase

13:00 – 15:00 **Session 3, Poster 1a and Lunch**

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

Quantifying nonlinear connectivity in the stretch reflex for chronic hemiparetic stroke in a pilot study
Presenter: Yuan Yang • Authors: Yuan Yang, Jun Yao, Julius P Dewald

Extension and flexion representations in M1 spatially cluster around the moving finger
Presenter: Naveed Ejaz • Authors: Spencer Arbuckle, Jeff Weiler, Erik A Kirk, Marcus Saikaley, Marc Schieber, Jorn Diedrichsen, Naveed Ejaz

Motor cortex embeds muscle-like commands in an untangle population response
Presenter: Abigail Russo • Authors: Abigail A Russo, Sean R Bittner, Sean M Perkins, Jeffrey S Seely, Brian M London, Antonio H Lara, Andrew Miri, Najja Marshal, Adam Kohn, Thomas M Jessell, Laurence F Abbott, John P Cunningham, Mark M Churchland

Stochastic dynamic operators: a framework for neural-based motor control and neural analysis
Presenter: Maryam Abolfath-Beygi • Authors: Maryam Abolfath-Beygi, Terence D Sanger, Simon F Giszter

Using intracortical microstimulation to inject instructions into premotor cortex
Presenter: Kevin Mazurek • Authors: Kevin A Mazurek, Marc H Schieber

Motor planning under uncertainty
Presenter: Laith Alhussein • Authors: Laith Alhussein, Maurice A Smith

DAY 3 Wednesday May 2

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

Moving motor control from the laboratory to the real world?
Organizer: Tamar Makin • Participants: Alaa Ahmed, Dagmar Sternad, Ilana Nisky, Tamar Makin

10:15 – 10:45 Break

DAY 3 Wednesday May 2 continued

10:45 – 13:00 **Session 6, Panel IV**

Reinterpreting proprioception based on musculoskeletal mechanics
Organizer: Lena Ting
Participants: Kyle Blum, Friedl de Groote, Raeed Chowdury, Richard Poppele

13:00 – 15:00 **Session 7, Posters 1b and Lunch**

15:00 – 16:40 **Session 8, Individual II**

Experts utilize the reticulospinal system more during individuated finger movements than non-experts
Presenter: Claire Honeycutt • Author: Claire Honeycutt

What dystonia can teach us about the normal function of the basal ganglia
Presenter: Terence Sanger • Author: Terence D Sanger

Aging reduces sensitivity to reward in a reaching task
Presenter: Erik Summerside • Authors: Erik M Summerside, Reza Shadmehr, Alaa A Ahmed

The foveal visual representation of the primate superior colliculus
Presenter: Ziad Hafed • Authors: Ziad Hafed, Chih-Yang Chen, Claudia Distler, Klaus-Peter Hoffmann

Contributions of the fronto-parietal reach network to goal-directed walk-and-reach movements of physically unconstrained rhesus monkeys in the Reach Cage
Presenter: Michael Berger • Authors: Michael Berger, Alexander Gail

16:45 – 17:15 **NCM Members' Meeting**

All Members of the Society for the Neural Control of Movement are invited to attend

DAY 4 Thursday May 3

08:00 – 10:15 **Session 9, Panel V**

Neurochemical basis of sensorimotor learning
Organizer: David Ostry
Participants: Charlotte Stagg, Takeo Watanabe, Winston Byblow

10:15 – 10:45 Break

10:45 – 11:15 **Early Career Award Talk**

Somatosensory feedback for real-world hand control
Andrew Pruszynski, University of Western Ontario

11:15 – 12:45 **Session 10, Perspective I**

Non-invasive neuromodulation for enhancement of plasticity and sensorimotor performance
Organizer: Christopher Buneo

Participants: Christopher Buneo, Vince Clark, Steve Helms Tillery, Jessica Richardson, Jamie Tyler

12:45 – 14:45 **Session 11, Posters 2a and Lunch**

15:00 – 19:00 **Free Time and Ticketed Excursions**

DAY 5 Friday May 4

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

Fast but smart enough to teach: rapid sensory feedback to guide motor learning
Organizer: Hongchul Sohn
Participants: Frédéric Crevecoeur, Chao Gu, David Franklin, Aiko Thompson

10:15 – 10:45 Break

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

The nervous system activates muscles to minimize internal joint stresses: evidence from quadriceps muscle activations during motor adaptation in the rat
Presenter: Matthew Tresch
Authors: Matthew Tresch, Cristiano Alessandro, Filipe Barroso, Qi Wei, Yasin Dhaher, Thomas Sandercock, Dinesh Pai

The molecular engram of procedural motor skill memories resides in layer 5 of the primary motor cortex
Presenter: Joseph Francis • Authors: Joseph T Francis, Peng P Gao

Divisively normalized integration of visual and proprioceptive motor memories for motor adaptation
Presenter: Takuji Hayashi • Authors: Takuji Hayashi, Yutaro Kato, Daichi Nozaki

Cortical control of vigor, but not timing or direction, in a center-out reach task in mice
Presenter: Teja Pratap Bollu • Authors: Teja Pratap Bollu, Samuel C Whitehead, Itai Cohen, Jesse H Goldberg

The effects of sensory matching errors in motor control
Presenter: Irene Kuling • Authors: Irene A Kuling, Eli Brenner, Jeroen B Smeets

Primary motor cortex (M1) encodes a value function consistent with reinforcement learning
Presenter: Joseph Francis • Authors: Venkata S Aditya Tarigoppula, John P Hessburg, John S Choi, David B McNiel, Brandi T Marsh, Joseph T Francis

12:45 – 14:45 **Session 14, Posters 2b and Lunch**

14:45 – 16:45 **Session 15, Panel VII**

Brain mechanisms of motor learning in health and disease
Organizer: Tibor Hortobagyi
Participants: Kelly Berghuis, Brad King, Beth Fisher, Brita Fritsch, Rachael Seidler

16:45 – 18:00 **Session 16, Keynote Address**

Shining light in the dark basement: The basal ganglia in action
Ann Graybiel, McGovern Institute for Brain Research at the Massachusetts Institute of Technology

18:00 – 19:00 **Closing Drinks Reception**

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Session 1, Panel I

Tuesday, May 1 8:00 – 10:15

Sensory gating - origins, mechanisms, functions

Shubo Chakrabarti[1], Kazuhiko Seki[2], Kathleen Cullen[3], James Kilner[4]

[1]Hertie Institute of Clinical Brain Research, Center for Integrative Neurosciences, [2]National Center of Neurology and Psychiatry, [3]Johns Hopkins University, [4]Institute of Neurology, University College London

Voluntary movements are critical for survival, but create an additional challenge for the sensory system. The sensory consequences of self-motion (re-afference) need to be accurately predicted to enable perception of the external sensory environment (ex-afference). It has now been shown across several species and modalities that sensory responses acquired during sensor motion are attenuated - a phenomenon termed sensory gating. However, the exact mechanisms by which sensory gating is achieved, its origins and most importantly its putative functions are still unclear. This panel brings together several neuroscientists studying sensory gating in a variety of disciplines and animal models to focus on the similarities and differences between gating mechanisms in different systems. Most importantly the panel wishes to engage in the discussion of the putative functions of gating and to delineate several hypotheses regarding its nature. Does gating simply reflect the subtraction of ego-motion during active movements or is it, in fact, part of a dynamic sensory modulatory circuit that refines and sculpts the sensory input based on a wide variety of factors such as predictions about the environment, behavioral context, sensory channels involved or novelty of input. Dr. Seki will introduce the topic and demonstrate that sensory gating, in the somatosensory system of nonhuman primates, is dominant in both spinal cord and primary sensorimotor cortices, and that they could be shaped via pre-synaptic inhibition at the spinal level. He will show that gating is not a simple attenuation but instead a flexible and dynamic modulation of sensory information depending upon the type of sensory input studied. He will argue that gating is extremely refined and an input-specific process. Dr. Kilner will introduce sensory attenuation in humans. Specifically, he will show data that are consistent with the hypothesis that there are at least two functionally and mechanistically distinct forms of sensory attenuation. Further, he will argue that sensory gating might be required for movement initiation to the extent that a failure of sensory attenuation will result in a failure in movement initiation. Dr. Cullen will discuss sensory gating in the vestibular system of the primate. Her results provide direct evidence that the sensitivity of individual cerebellar output neurons tracks the difference between predictive and feedback signals, consistent with the computation of sensory prediction error. Unexpected sensory inputs are initially represented as exafference, however as unexpected sensory input becomes expected during active movements the brain's internal model is updated to re-enable the distinction between vestibular reafference and exafference. Dr. Chakrabarti will discuss gating in an active touch system - the rodent whisker system. He will show that gating occurs in the brainstem and is dependent on corticofugal input. He will further show, that like in the primate limb, gating is channel specific and is particularly evident in ascending channels processing touch. Finally he will speculate on the relation of sensory gating to the correction of ego-motion and its dependence on behavioral context. Overall, the panel wishes to demonstrate that sensory gating is part of a sophisticated and input-specific modulation of sensory traffic which might be used to dynamically shape sensory input by a wide range of factors such as behavior, self-motion, and novelty.

Session 2, Panel II

Tuesday, May 1 10:45 – 13:00

The role of practice in motor learning: from sensorimotor adaptation to mastering de-novo skills

Gelsy Torres-Oviedo[1], Adrian Haith[2], Virginia Penhune[1], Steven Chase[1]

[1]University of Pittsburgh, [2]Johns Hopkins University School of Medicine

It is well accepted that practice is necessary to mastering any new skill. Existing theories of why practice may be so necessary have framed it as either a period of exploration, allowing for identification of better ways of performing a task, or as one of consolidation, promoting a change in representation that permits more efficient, automatic execution. However, much remains unknown about the principles, mechanisms and limitations of motor learning through practice. What aspects of performance require practice to improve? Are there limits to these changes? Does the efficacy of practice differ in different populations (e.g. young versus old)? What factors determine how effective practice is at improving eventual performance? This panel will present four distinct lines of research which converge on the common problem of the role of practice in motor learning. We will show behavioral, theoretical, neurophysiological and neuroimaging results to address both basic and clinical questions related to practice. Adrian Haith will show that, across a variety of paradigms, a key behavioral effect of practice is to reduce the latency at which actions can be generated in response to external events. He will argue that this provides evidence for a change in underlying representation of task performance. Steve Chase will present data from a long-term brain-machine interface learning task performed by Rhesus macaques, and assess how the amount of practice affects the reorganization of the neural encoding of velocity. He will argue that short- and long-term practice drive qualitatively distinct forms of neural reorganization. Gelsy Torres-Oviedo will show that the generalization of movements from trained to untrained situations is determined by the similarity between training and testing conditions regardless of the extent of practice, highlighting the importance of the context where tasks are practiced. She will also present preliminary results indicating that extensive practice adapting to perturbations to walking leads to slower decay of motor memories when the perturbation is removed. Virginia Penhune will review evidence from behavioural and functional neuroimaging experiments addressing the effects of practice on neural representation of skill during sequence learning. She will also discuss the impact of age of start of practice on brain structure in the context of musical training. We will conclude with a 20-minute discussion about the role of practice in motor skill learning. John Krakauer will join the panel to help catalyze a stimulating discussion, focusing on potential mechanisms of practice, possible common principles of practice across different learning tasks, and translatability of principles of lab-based practice to real-world skill learning and rehabilitation.

Session 4, Individual Presentations I

Tuesday, May 1 15:00 – 17:00

Quantifying nonlinear connectivity in the stretch reflex for chronic hemiparetic stroke in a pilot study

Yuan Yang[1], Jun Yao[1], Julius Dewald[1]

[1]Northwestern University

Unilateral brain injuries from a stroke can cause hyperactive stretch reflex activity. There is evidence that hyperactive stretch reflex activity is likely associated with an increased reliance on the reticulospinal system[1]. We hypothesize that oligo-synaptic interactions via the corticoreticulospinal (CRST) system may increase the complexity of long-loop reflexive control, resulting in a more dominant nonlinear connectivity between stretch stimulation and muscle activity[2]. Very recently, we proposed an advanced method for the assessment of nonlinear connectivity and its time delay that cannot be exploited by linear coherence approaches[3]. In this study, we applied our nonlinear analysis method to investigate nonlinear connectivity in the stretch reflex of individuals with chronic hemiparetic stroke. We recruited three participants with chronic hemiparetic stroke and two age-matched healthy controls. A multi-sine wave continuous perturbation was applied to the elbow joint while stroke participants performed shoulder abduction (SABD) tasks using their paretic arms, at the level of 0% (arm supported), 20% and 40% of their maximum SABD voluntary torques. Stroke-induced synergetic elbow flexion torques were averaged across the 3 stroke participants, separately at 20% and 40% SABD levels. Then in healthy controls, the same elbow perturbation was applied to the dominant arm while they generated SABD and elbow flexion torques at the level that matched the synergetic elbow flexion in stroke subjects. EMG activities of elbow flexors (i.e. brachioradialis, biceps brachii) of the tested arm were recorded. The nonlinear connectivity between the perturbation and EMG were calculated using our nonlinear method. The time delay was estimated based on the relative phase between the continuous perturbation and EMG, which is influenced by both spinal and supraspinal loops. We found that stroke subjects show increased nonlinear connectivity and prolonged time delay as compared to healthy controls. Furthermore, nonlinear connectivity and time delay increase with synergic elbow flexion (associated with SABD levels) in only stroke subjects. As spinal reflex latency would not change after stroke, the prolonged delay is likely related to supraspinal reflex contributions. Increased nonlinear connectivity and delay may be originated from the CRST, since higher SABD level increases the usage of CRST in stroke subjects[1]. This study, for the first time, provides evidence of changes of nonlinear connectivity in the stretch reflex after hemiparetic stroke, indicating that nonlinear analysis may provide new insights into abnormal stretch reflex activity caused by a stroke. References: [1] McPherson JG, Stienen AH, Drogos JM, Dewald JPA. Arch Phys Med Rehabil, online ahead of print, DOI:10.1016/j.apmr.2017.06.019. [2] Yang Y, Dewald JPA, et al, Eur J Neurosci, online ahead of print, DOI:10.1111/ejn.13692. [3] Yang Y, et al (2016). Int. J Neural Syst. 26(1): 1550031.

Extension and flexion representations in M1 spatially cluster around the moving finger

Spencer Arbuckle[1], Jeff Weiler[1], Erik Kirk[1], Marcus Saikaley[1], Marc Schieber[2], Jorn Diedrichsen[1], Naveed Ejaz[1]

[1]Western University, [2]University of Rochester Medical Center

Individual neurons in the hand area of the primary motor cortex (M1) encode both which finger(s) moved, as well as the direction of these movements (Schieber, 1990). Although the preferences of M1 neurons for different fingers is reflected in their coarse, lateral-to-medial somatotopic arrangement on the cortical sheet (Indovina and Sanes, 2001), we currently do not know how movement direction preferences of M1 neurons are spatially organized. We hypothesized that groups of neurons that control extension and flexion movements along the same joint tend to spatially cluster together, perhaps to optimize control. To test this idea, we used fMRI to measure cortical activity maps during extension and flexion finger presses in humans, and compared these maps with population responses of M1 neurons during similar actions in monkeys. Since fMRI will preferentially measure hand representations that lie at coarse, rather than fine-spatial scales (Kriegeskorte and Diedrichsen, 2016), we predicted that fMRI activity maps for extension and flexion movements should look very similar, but substantial differences should appear in single-cell responses. We trained 9 healthy, humans to perform voluntary isometric finger extension and flexion movements with each of the 5 right-handed fingers. Participants made finger presses at 3 different target-force levels (range: 1.0N-2.5N) inside an fMRI scanner (7T, 1.4mm3). We also recorded muscle activity from 14 upper-limb locations using surface electromyography. Single-unit recording data from 2 monkeys performing a similar task (Schieber 1993) were also analyzed. fMRI activity maps for each finger were overlapping, but a coarse, lateral to medial somatotopic arrangement of fingers was observed. Activity maps for extension and flexion movements of the same finger looked highly similar. We used the cross-nobis distance (Walther et al., 2015) to quantify the dissimilarity between activity maps for different fingers moving in the same direction and the same finger moving in different directions. Dissimilarities for fingers and directions were greater than zero, indicating that fMRI maps carried significant information regarding both movement dimensions. On average, however, dissimilarities for fingers were significantly larger than those for movement direction ($t_8 = 5.30$, $p<0.001$), demonstrating that the maps contained more information about the finger, rather than the direction it moved in. EMG activity patterns during extension and flexion movements were equally dissimilar for different fingers and movement directions indicating that similarity between extension and flexion fMRI activity maps could not be explained by the structure of descending muscle activity. In contrast to the fMRI activity maps, dissimilarities in single-unit population responses for fingers and movement direction were not reliably different. Overall, our results demonstrate that although finger movement direction can only weakly be inferred from fMRI activity maps, single-unit recordings carry much more information regarding which finger moved. Our results suggest that movement direction representations exist at a finer spatial scale than those for fingers, with representations for movement along a joint spatially clustering together.

Motor cortex embeds muscle-like commands in an untangled population response

Abigail Russo[1], Sean Bittner[1], Sean Perkins[1], Jeffrey Seely[1], Brian London[2], Antonio Lara[1], Andrew Miri[1], Najja Marshal[1], Adam Kohn[3], Thomas Jessell[1], Laurence Abbott[1], John Cunningham[1], Mark Churchland[1]

[1]Columbia University, [2]SeatGeek, [3]Albert Einstein College of Medicine

A central question in the study of motor cortex has been whether its activity resembles muscle activity and if not, why not? Primate motor cortex is as close as one synapse from motoneurons and corticospinal neurons can measurably impact muscle activity. One might thus expect neural activity to resemble muscle commands. Yet, non-muscle-like signals are often prevalent in the population response. While these signals are frequently hypothesized to encode 'high-level' movement parameters, we used a novel task to

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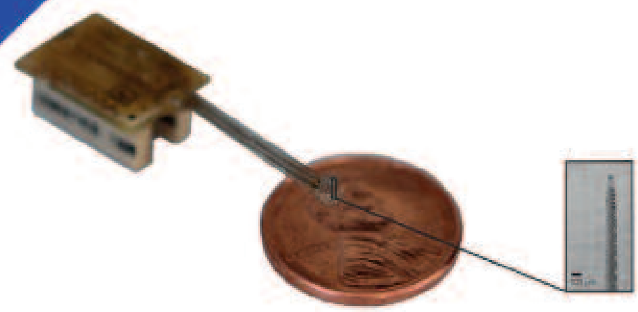

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Electrophysiology • Optogenetics • Animal Behavior explore a different class of explanation. Neural and muscle responses were recorded as monkeys cycled a hand-pedal to progress through a virtual environment. Single-neuron and muscle responses shared many surface-level features, and muscle activity could be decoded from neural activity. However, the neural population response was dominated by smooth, non-muscle-like signals. Although these signals superficially resembled high-level parameters such as velocity or position, they did not reverse between forward and backward cycling, violating a central prediction of encoding hypotheses. We considered an alternative explanation: might the observed neural trajectories reflect the requirements of a recurrent neural network that must use internal dynamics to generate outgoing commands? We introduce a metric, trajectory 'tangling', relevant to the function of such networks. Tangling is high if similar neural states are associated with dissimilar derivatives. High tangling indicates potential dynamical instabilities, implying that the network is noise-sensitive and/or must rely on external inputs. To remain stable, a network should produce trajectories with low tangling. Consistent with this prediction, neural trajectories were dramatically less tangled than the corresponding muscle trajectories. This effect was also present during a center-out reaching task and in mice during a precision-pull and locomotion task. However, low tangling was not a generic feature of cortex: activity in somatosensory and visual cortices did not avoid tangling. We wondered whether the need to encode muscle activity while achieving low tangling might largely explain the motor cortex population response. We used a novel optimization approach to predict motor cortex activity based on those two constraints. Optimization did indeed produce a predicted population response that was quantitatively and qualitatively very similar to the empirical response. Network simulations confirmed that the predicted population response could indeed be produced with much greater noise robustness than alternative responses with higher tangling. In summary, the dominant signals in the motor cortex population response can be explained by the need to maintain low tangling while encoding muscle commands. We therefore propose that the smooth signals in motor cortex have a computational rather than a representational function: they allow motor cortex to stably and robustly generate descending commands.

Stochastic dynamic operators: a framework for neural-based motor control and neural analysis

Maryam Abolfath-Beygi[1], Terence Sanger[1], Simon Giszter[2]

[1]University of Southern California, [2]Drexel University

Stochastic dynamic operator theory has been introduced as a general framework for distributed control with a wide range of applications, to model the system dynamics controlled by a network of distributed controllers. In neural-based motor control, where neurons are the distributed controllers, the SDO framework quantifies the nonlinear effects of individual neurons on the state dynamics and allows for the linear superposition of the effect of these neurons in a probabilistic domain. In this framework, each neuron has an SDO operator, which quantifies the dynamic effect of the spiking activity of that neuron on the movement variables or the neural network state. The choice of state variables varies depending on the problem. We validate this theory using a known simulated neural network as 'ground truth'. The simulated network is based on Hodgkin-Huxley model and developed by Rybak Shevtsova, and Markin, for modeling the organization of spinal cord in rhythmic locomotion. It is a two-level central pattern generator (CPG) model of a neural circuit, with 27 populations, which generates locomotor activity in four muscles. From the predictive control point of view, we demonstrate that the SDO framework is able to predict the activity of motor neurons using partial neural recordings of higher-layer neurons. In addition to being a control framework, SDOs provide a new method for neural analysis which describes the state-dependent effect of a neuron on the change in the movement state or another neuron's activity. Here, we consider the SDO framework as a neural analysis technique to the known circuit and show that SDOs are capable of capturing the network functional structure. Since SDO framework is capable of describing oscillatory behavior, we investigate whether the SDO analysis is able to discover the neurons participating in the central pattern generator (CPG) layer of the network. The pattern formation layer follows the dynamic of CPG one layer below. We discovered that the pattern of SDOs is able to differentiate between the CPG neurons responsible for generating the circuit's rhythm and the pattern formation generator neurons driven by the CPG layer with similar neural activities. The second application of SDO framework as a neural analysis technique also allowed us to develop a connectivity analysis technique at a mesoscopic and macroscopic neural circuit level which is able to discover functional pathways. We demonstrate the connectivity results derived by using stimulation and SDOs in the known network.

Using intracortical microstimulation to inject instructions into premotor cortex

Kevin Mazurek[1], Marc Schieber[1]

[1]University of Rochester

The role of premotor cortex (PM) traditionally has been related to the preparation of motor plans for producing specific movements. PM receives inputs from parietal cortical areas representing processed visuospatial information, translates that information into plans for particular movements, and communicates those plans to the primary motor cortex (M1) for execution. Consistent with this general function, intracortical microstimulation (ICMS) in PM of sufficient frequency, amplitude, and duration has been shown to evoke complex movements of the arm and hand that vary systematically depending on the locus of stimulation. Using ICMS at amplitudes and frequencies too low to evoke muscle activity, however, we found that ICMS in PM can provide instructions to perform specific actions. Two monkeys previously had been trained to perform a reach-grasp-manipulate (RGM) task using visual cues that instructed which of four objects to manipulate. We trained these monkeys to use low-amplitude ICMS at arbitrary PM locations as instructions for performing the same movements. Initially, low-amplitude ICMS was delivered at an arbitrary PM location concurrently with each of the visual cues. As the visual cues then were gradually dimmed, the monkeys learned to associate even brief, low-frequency, PM-ICMS instructions with specific RGM movements. Eventually, using only the ICMS instructions, both monkeys performed the task with success rates, reaction times, and movement times equivalent to or better than when using visual cues. Performance was unimpaired when ICMS was delivered through a different single electrode to instruct each object, and remained unimpaired after frequency information was eliminated by delivering ICMS pulses at stochastically jittered inter-pulse intervals. Furthermore, after the assignments of ICMS at different PM loci to instruct particular RGM movements had been shuffled, the monkeys re-learned the shuffled assignments, confirming that the arbitrary associations were learned, not fixed. At the low current amplitudes used to deliver ICMS instructions, stimulus-triggered averaging showed a small output effect from only one PM electrode in one monkey, indicating that the monkeys could not have used twitches in different muscles as instructions. Our findings demonstrate that low-amplitude, low-frequency, short-duration ICMS at different PM loci produces distinguishable experiences that the subject can report by performing arbitrarily-associated movements, providing a novel means of injecting information into the nervous system.


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Motor planning under uncertainty

Laith Alhussein[1], Maurice Smith[1]

[1]Harvard University

We often initiate actions when uncertain about the movement plan. For example, when moving one's hand to catch a fast-moving ball in anticipation of its arrival. Experimentally, motor planning under uncertainty has been studied using the "go-before-you-know" paradigm. Here, subjects are presented with two possible targets, one of which is cued, but only after movement onset. In response to the uncertainty, individuals generally initiate movements in a direction in between the two targets. The predominant explanation for these intermediate initial movements is that such movements reflect an average of the motor plans that would arise from each of the potential targets (Cisek 2007; Erlhagen and Schoner 2002; Gallivan et al. 2015; Stewart et al. 2013; Tipper et al. 1998; Chapman et al. 2013; Gallivan et al. 2017; Ghez et al. 1997). While recent work has suggested that this motor averaging behavior is not obligatory (Wong and Haith 2017), here we further challenge this long-standing hypothesis and demonstrate that motor averaging is unlikely to occur at all. One particularly influential study, performed by Stewart and colleagues (2014), provided evidence for motor averaging behavior by using obstacles to distort individual-target motor plans and correlating the change in intermediate movements under uncertainty with these distortions. An alternative explanation for the Stewart et al. results is that the observed behavior reflects a single motor plan that optimizes for task success by maintaining a safety-margin around the obstacle; however, the specifics of the experimental design confounded this optimization with motor averaging. Here we present two experiments that allow for a systematic dissociation between planning for task-success and motor averaging. In experiment 1, we altered the obstacle paradigm employed by Stewart et al. to more thoroughly examine the relationship between individual-target motor planning and motor planning under uncertainty. Specifically, this was accomplished by placing obstacles at additional locations. In experiment 2, we used a force-field (FF) adaptation paradigm in which movements to two lateral targets were perturbed with FF's that were opposite in direction to the FF administered to a center (intermediate) target. After training, subjects were exposed to the same uncertain, two-target trials used in experiment 1, in which both lateral targets were presented as potential reach options. During uncertainty, motor averaging would predict that participants should now average the force patterns learned for the lateral targets. However, a plan aimed at optimizing task success would predict that participants should produce the force pattern appropriate for the planned intermediate movement, which was opposite to that trained for both lateral targets. In both experiments 1 and 2, we find that motor averaging fails to predict behavior observed for motor planning under uncertainty. Instead, our results indicate that when faced with uncertainty, individuals form a single motor plan that optimizes for task success by leveraging new information as it becomes available.

Session 5, Panel III
Wednesday, May 2   08:00 – 10:15

Moving motor control from the laboratory to the real world?

Alaa Ahmed[2], Dagmar Sternad[3], Ilana Nisky[4], Tamar Makin[1]

[1]University College London, [2]University of Colorado, [3]Northeastern University, [4]Ben Gurion University of the Negev

As the brain is shaped by experience, real-life constraints on behaviour should be reflected in the neural processing of perception and action. Yet, this major driver of brain organisation and plasticity is largely overlooked in contemporary motor control research. While simplified and highly controlled paradigms have been a valuable design principle, it limits our ability to explore the complexities of neural processing. Here we present research that aims to bring the real world into the lab. First, Alaa Ahmed will present a computational framework with which we can understand traditional lab-based movement tasks and extend such paradigms to the real world. She will present results demonstrating that motivation, risk, and costs such as effort and instability significantly alter motor performance even in simple reaching. These changes can be understood within a framework of a movement utility determined by the reward to be obtained and the costs to acquire it. Second, Dagmar Sternad will present a line of studies that examine the control of complex underactuated objects, such as a cup of coffee. Starting with mathematical analyses of the task, the experiments show that humans develop skill by: 1) finding error- and noise-tolerant strategies, 2) exploiting solutions with dynamic stability, and 3) optimizing predictability of object dynamics. These results are the basis for developing propositions about the controller: complex actions are generated with dynamic primitives. Third, Ilana Nisky will discuss robot-assisted surgery as a natural and complex behaviour requiring precise 6D manipulation of instruments that are learnt in a steep learning curve. The teleoperated nature of robot-assisted surgery allows for unobtrusive measurement of the kinematics of the instruments and the visual stream, both in real-life surgery and in the lab. Ilana will show how task constraints, teleoperation control parameters, and surgical experience affect the kinematics of needle-driving and perception and action in robot-assisted grasping. Finally, Tamar Makin will show how everyday compensatory strategies, adopted by individuals with congenital handlessness, shape brain reorganisation. Individuals missing a hand will learn to use multiple body parts to substitute for that missing hands' function. Tamar will show, using neuroimaging, how these compensatory behaviours map onto altered topographic representation across the sensorimotor homunculus. This line of studies suggest that altered inputs due to real-life adaptations in motor control are strong drivers of large-scale brain reorganisation. In sum, by combining across simple and complex tasks in real-life context, and by using complementary experimental models and approaches, the session will provide a broad outlook on how motor control in the real world shapes and challenges the brain.

Session 6, Panel IV
Wednesday, May 2   10:45 - 13:00

Reinterpreting proprioception based on musculoskeletal mechanics

Lena Ting[1], Kyle Blum[1], Friedl De Groote[2], Raeed Chowdury[3], Richard Poppele[4]

[1]Emory University and Georgia Tech, [2]KU Leuven, [3]Northwestern University, [4]University of Minnesota

Our understanding of sensorimotor control is shaped by the idea that muscle spindles provide length and velocity feedback of muscles for motor control. However, there are important cases where this assumption does not hold and could be limiting our ability to understand both normal and abnormal motor control. This panel focuses on revisiting classic views of muscles spindle function in light of new experimental and modeling studies that provide insight into a number of proprioceptive phenomena in the literature based on muscle and musculoskeletal mechanics. Such computational models are critical for predicting the role of sensory encoding in motor function, for improving neural prosthetics, and for understanding the interactions between neural and musculoskeletal dynamics in normal and impaired sensorimotor function. Lena Ting will provide evidence for muscle-spindle derived force and acceleration-like signals in shaping predictive motor outputs in human and animal reactive balance control. Kyle Blum will present a model of muscle spindle sensory encoding based on muscle cross-bridge dynamics and neural currents dependent on muscle fiber force and its first time derivative, i.e. yank. This multiscale model robustly reproduces a wide range of properties of muscle spindle firing, including different subclasses of muscle spindle afferents behaviors, fractional power relations with stretch velocity, and history-dependent responses observed in vivo such modulation of afferent responses due to prior movement. Friedl De Groote will demonstrate contributions of abnormal muscle and proprioceptive dynamics in simulations of clinical tests of spasticity in children with cerebral palsy. Proprioceptive feedback from muscle fiber length and velocity fails to explain data from experimental and clinical assessments of spasticity. However, the interaction between force encoding in muscle spindles and history-dependent muscle dynamics explains experimentally observed hyperresistance to imposed joint motion. Raeed Chowdhury will demonstrate that apparent limb-axis encoding in early proprioceptive streams can arise directly from a simple convergence of muscle spindles based on musculoskeletal mechanics alone without additional sensory processing. Further, classic models of proprioceptive coding in somatosensory cortex that neglect musculoskeletal geometry fail to predict some salient features of neural activity in during reaching--namely directional tuning that depends on posture, and the difference in neural population activity during active and passive movements. However, a model that incorporates a biomechanical model of the arm can explain these features. Richard Poppele will then lead a discussion about how recent modeling work and other evidence provides insights about proprioceptive coding, and its role in normal and impaired sensorimotor control.

Session 8, Individual Presentations II

Wednesday, May 2 15:00 - 16:40

Experts utilize the reticulospinal system more during individuated finger movements than non-experts

Claire Honeycutt[1]

[1]Arizona State University

While the corticospinal tract is critical for learning, a recent study published in Neuron shows that there is a shift from the use of cortical to subcortical structures following intense training. It is widely acknowledged that the learning of a novel task requires substantial cortical input. However, following training rats with bilateral motor cortex lesions can perform a sequence of precisely timed lever presses i.e. if sufficiently trained prior to lesion, rats can perform lever presses without the motor cortex. Thus, the brainstem is capable of executing movements if they are significantly practiced. Still, the Kawai paper was conducted in rats during a predominately reaching task. The human cortex is significantly more developed and utilized more extensively during movement. Further, while reaching tasks have been shown by numerous groups to utilize the brainstem, the role of the brainstem and reticulospinal pathways in individuated movements of the fingers is more controversial. Indeed, our own work has indicated that individuated movements of the fingers do not use reticulospinal pathways; however, the previous chosen task, index finger abduction, is an unusual task, begging the following question: would individuated finger movements utilize the reticulospinal system (as assessed by startReact) if they were trained or highly practiced? We performed 2 experiments to address this question. First Experiment: we evaluated the impact of a 2-week training regimen on the ability to elicit StartReact. We found that following training individuated movements of the hands (specifically index finger abduction) become susceptible to startReact. Before training, Startle+ trials were not different from Startle- (Δ=0.001ms; P=0.7) showing an absence of startReact. After training Startle+ trials were faster than Startle- (Δ=8.7; P=0.004). This indicated that following intense, repetitive training there is a shift to utilization of pathways associated with startReact (i.e. reticulospinal tract). However, it was unclear if startReact would be sensitive enough to detect task expertise in already trained tasks. Second Experiment: we evaluated 9 Expert and 9 Non-Expert typists. Analysis of the keystroke data revealed that startReact was present in all fingers of Expert typists but none of the fingers in Non-Experts. In Experts, Startle+ trials were faster than Startle- trials for the thumb (Δ=0.024s; P=0.003), index (Δ=0.029s; P=0), middle (Δ=0.014s; P=0.04), ring (Δ=0.029s; P=0.002), and little (Δ=0.029s; P=0). There was no difference for any of the fingers in the Non-Expert population: thumb (Δ=0.005s; P=0.618), index (Δ = -0.005s; P=0.009), middle (Δ=-0.001; P=0.823), ring (Δ=-0.006s; P=0.37), and little (Δ=0.018; P=0.054). We conclude that Experts utilize the reticulospinal system to execute highly trained tasks indicating that the result from rats pertains to humans as well. Our results are significant because they indicate that the reticulopsinal system is utilized 1) in individuated finger movements in humans and 2) more in highly trained tasks. These results show that startReact is a measurable behavioral indicator of motor learning capable of detecting shifts in brainstem utilization in sophisticated movements of the fingers.

What dystonia can teach us about the normal function of the basal ganglia

Terence Sanger[1]

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from up to 100 microelectrode channels in GPi and motor thalamus in awake unrestrained children. Recordings in 12 children with secondary dystonia reveal very low neural firing rates at rest (<1hz) that increase with movement (5-10hz) in both GPi and thalamus. Furthermore, pairs of neurons within individual nuclei show highly significant spike coincidences with sub-millisecond precision even between neurons that can be millimeters apart. While this pattern likely reflects widespread diffuse injury to basal ganglia, it also provides an opportunity to examine the behavior of a sparse interconnected network of surviving neurons. If cells fire rarely but with precise relative spike timing, this permits an effective digital code, in which spatial patterns rather than individual cells transmit information. Given an estimated 100 million neurons in GPi for instance, it is theoretically possible to allocate 10,000 unique two-neuron patterns to every millisecond of a human life. This suggests a new model of basal ganglia function, in which the basal ganglia-thalamus circuit memorizes every state-output mapping that has ever occurred in the person's life. Dopamine, acetylcholine, oxytocin, substance P, endorphins, and other neuromodulators determine whether each motor memory is rewarding, risky, important, unimportant, social, avoidant, painful, or pleasurable. Future behavior is modified by selection and replay of motor memories based on current state and desired outcome. The output of the basal ganglia circuit modulates cortical excitability in order to selectively enhance the desired sensory-motor dynamics. The computational model is closest to a radial basis-function network with nodes allocated at each datapoint, augmented by assigned valence from neuromodulators. Generalization is restricted to a small region unless there are multiple repetitions of practice in different situations that can "pave" the space of possible initial conditions. Variability of motor output is due to variability in the high-dimensional initial conditions, and continued practice reduces variability by learning the correct motor output that fills in "holes" in the state space. This model explains important behavioral observations that have been difficult to reconcile with standard computational models based on recursive learning rules: (1) one-shot learning, (2) lack of interference between different motor memories, (3) lack of motor forgetting, (4) poor generalization of complex motor skills outside the conditions in which they were learned. Through simulations, the effectiveness of this surprisingly elegant brute-force learning algorithm will be demonstrated. The result of injury will also be demonstrated and the effect on previously learned skills and the ability to acquire new skills is consistent with psychophysical results from human patients with dystonia.

Aging reduces sensitivity to reward in a reaching task

Erik Summerside[1], Reza Shadmehr[1], Alaa Ahmed[1]

[1]University of Colorado

Background: The vigor (peak velocity as a function of distance) with which we move depends on both the opportunity for reward and the effort required to obtain reward. As we age, movement vigor decreases. Is this reduction due to a reduced sensitivity to reward, increased sensitivity to effort, or both? Aging accompanies a reduction in dopamine, a proxy for subjective rate of reward. However, the effort to move also increases with aging. During walking, metabolic power increases in the elderly, and these adults prefer slower speeds. We sought to measure both sensitivity to reward and an objective measure of effort as a function of aging in a common task: reaching. We found that with reaching, older adults exhibited a reduced sensitivity to reward, with no accompanying changes in metabolic costs. Methods & Results: In Exp. 1, we measured sensitivity to reward during reaching movements. Twenty young (27.5 years) and twelve elderly (75.1 years) adults moved a cursor from the center of a large circle (r=14cm) through the arc of the circle in one of four alternating 100° quadrants. The protocol consisted of 4 blocks. In each block, a single quadrant was paired with reward. To minimize accuracy costs, the only requirement for success was to pass the circle through any point along the quadrant. We compared reaction time, peak velocity, duration, crossing point, and maximum excursion when a quadrant was paired with reward and when that same quadrant was not rewarded. When movements were unrewarded, reach kinematics were indistinguishable between young and elderly. In the presence of reward, younger subjects decreased reaction time (-5%), increased peak velocity (+2%), increased maximum excursion (+4%) and decreased duration (-5%). In the elderly, reward had no effect on any measurements. Therefore, reward led to increased reach vigor in young but not old. This reduced reward sensitivity in older adults may be a result of increased effort. To test this, we performed a second experiment to compare the metabolic cost of reaching in healthy young and old adults. Sixteen young adults (27.4 years) and ten elderly adults (76.0 years) made forward and backward movements across 20 blocks, each lasting ~5 minutes. Each block consisted of one of two distances (10 or 20cm) and one of five durations (300-2100ms). Metabolic rate was measured via indirect calorimetry. We found an increase in metabolic cost as a result of speed and distance, but not as a result of age. Therefore, with aging there was a reduced sensitivity to reward during reaching, but no evidence for increased effort costs of the movement. Discussion: Reward led to increased vigor of reaching in young adults, but not for elderly adults. In both young and the elderly, the energetic cost of reaching increased with speed of the movement and its distance, demonstrating that metabolic costs of reaching are not significantly different in the two groups. Taken together, the results suggest that the failure of elderly adults to respond to reward was not due to an added effort cost, but instead because of a decrease in sensitivity to reward.

The foveal visual representation of the primate superior colliculus

Ziad Hafed[1], Chih-Yang Chen, Claudia Distler, Klaus-Peter Hoffmann

[1]Centre for Integrative Neuroscience

The primate superior colliculus (SC) is critical for saccade generation. Anatomically, the SC contains topographic maps, of either retinotopic location (for visual representations) or saccade endpoints (for motor representations), exhibiting "foveal magnification". However, estimates of such magnification are based solely on extrapolating extra-foveal measurements. Given the logarithmic compression nature of SC topography, a variety of models can fit peripheral measurements very well while still grossly under-estimating foveal magnification. Moreover, even though motor responses have been reported for microsaccades in the deeper layers, SC visual representations associated with tiny foveal eccentricities remain completely unexplored. This creates a pressing need to study foveal representations, especially given that foveal processing is a mode of operation that we rely on heavily in our daily life, and given that visual guidance is necessary for ensuring precise, but tiny, gaze shifts during high acuity visual tasks. We recorded from the SC foveal visual representation in 2 awake and 2 anesthetized monkeys. In the awake animals, we recorded from 121 neurons with foveal preferred eccentricities and compared their visual response field (RF) characteristics to those of >200 more eccentric neurons. In the anesthetized animals, we densely mapped preferred RF locations and related them to SC anatomy, mapping 66 foveal sites and comparing them to >100 more eccentric ones. We systematically moved our electrodes by 100, 250, or 500 micrometer steps along the two-dimensional SC surface. Foveal SC neurons' RF's were strongly skewed and lateralized, having sharp cutoffs at the "foveal edge" of the visual representation. RF skew decreased progressively with increasing eccentricity, along with an exponential increase in RF size. Such increase also happened within the central foveola region (<0.5 deg radius), suggesting non-uniform sampling of visual space even within the smallest eccentricities. Foveal visual neural sensitivity was also as strong as peripheral neural sensitivity, and deeper recordings encountered microsaccade-related discharge. Our dense mappings of SC surface topography revealed a highly orderly foveal representation, which was continuous with peripheral topography. We used our mappings to develop a 3-D model of the SC's topographic foveal visual representation, demonstrating more than twice the foveal magnification factor predicted by classic models extrapolating peripheral measurements. In all, our results demonstrate strong laterality of visual representations in the foveal SC, non-uniform sampling of space, high neural sensitivity, and a surprisingly large foveal magnification factor. The magnification and continuity of foveal topography at this level of detail have implications on the potential impacts of small eye movements on visual coding, and might also explain certain characteristics of microsaccade amplitude distributions.

Contributions of the fronto-parietal reach network to goal-directed walk-and-reach movements of physically unconstrained rhesus monkeys in the Reach Cage

Michael Berger[1], Alexander Gail[1]

[1]German Primate Center

Neural activity of motor, premotor and parietal networks in the primate brain is usually studied in the context of hand, arm, eye or head movements, in rare cases during locomotion on a treadmill. It is unknown how these fronto-parietal sensorimotor areas encode goal-directed full-body movement when approaching remote targets by walking. Furthermore, cortical contributions to planning and control of forelimb (arm) movements during walking might differ from planning and control of goal-directed reaching. We addressed these questions in a newly developed structured environment for wireless neurophysiological recording from physically unrestrained rhesus monkeys (Reach Cage). The Reach Cage incorporates physical reach targets with computer-controlled RGB-LED illumination and capacitive proximity sensors that can be placed on various positions within the cage. We trained two physically unconstrained rhesus monkeys to conduct visually instructed, delayed or memory-guided reaches towards targets near and far from their fixed starting position. Near targets could be reached immediately from the starting position, while far targets required the monkey to first perform a walking movement to approach the targets. Wrist movement was partly tracked using video-based motion capture of fur staining. We wirelessly recorded full-bandwidth (30 ksmp/s) activity from up to 128 of the 192 implanted electrodes of six chronic floating microelectrode arrays distributed over the parietal reach region (PRR), dorsal premotor cortex (PMd), and the hand/arm region of the primary motor cortex (M1). Preliminary results show that activity is selective for near target locations during preparation and execution, as known from experiments using physical constraints such as a primate chair and head-fixation. Directional selectivity for far targets is less pronounced than for near targets during preparation, walking and reaching. The overall activity level in PRR and PMd is low during walking but higher during the goal-directed reaches following the walking (target approach). In M1 the activity level is similar during both phases. The results suggest that in unrestrained animals PRR and PMd encode primarily immediate goal-directed reach movements, similar to more constraint settings, but are less selective for the direction of goal-directed full-body movements or planning of reaches following walking movements.

Session 9, Panel V

Thursday, May 3   8:00 – 10:15

Neurochemical basis of sensorimotor learning

David Ostry[1], Charlotte Stagg[2], Takeo Watanabe[3], Winston Byblow[4]

[1]McGill University, [2]University of Oxford, [3]Brown University, [4]University of Auckland

In recent years, there has been progress towards understanding the computational processes associated with sensorimotor learning along with the associated neural structures and electrophysiological properties of learning. However, it is less clear how these computations are implemented by the molecular mechanisms in these structures. Current neuroimaging work using fMRI identifies which parts of the brain are responsible for learning but leaves open the question what they are doing, and could obscure the fact that these structures may implement different processes at different phases of learning. Insight into molecular mechanisms underlying learning can come from magnetic resonance spectroscopy (MRS) which provides measures of neurochemical concentrations but until recently has been limited to individual measures obtained over a relatively long period of time. However, new acquisition sequences are becoming available that can better track neurochemical concentrations over time thus allowing us to link chemical changes with phases of learning. The presentations in this session focus on using MRS in a functional manner to understand the nature and the time course of learning. We begin by examining the role of gamma-Aminobutyric acid (GABA), an inhibitory neurotransmitter, and its relation to electrophysiological measures of cortical excitability, and to plasticity following stroke. We then consider interplay of inhibition and excitation by examining the relative contribution of GABA and glutamate to the acquisition and stabilization of new sensorimotor skills. Stagg will discuss recent work investigating the role of inhibition in motor plasticity. A significant body of work in animal models has highlighted the necessity of a decrease in local inhibition in cortical LTP-like plasticity. Using both MRS and paired-pulse TMS approaches, she will show GABA decreases in healthy subjects during learning of a motor task, and after relearning of motor function following stroke. In rodent stroke models, it has been shown that there are increases in tonic GABA signalling which impede motor recovery. Byblow will illustrate how MRS and neurophysiological techniques reveal signatures of aberrant GABAergic inhibition in the human motor cortex in people with motor deficits at the sub-acute and chronic stages after stroke. These processes may influence the dynamics of motor recovery early after stroke. Watanabe will discuss the neurochemical dynamics of visual skill learning. Using MRS, he tracked the concentration of glutamate divided by the concentration of GABA as an excitation to inhibition (E/I) ratio. He shows that continuous training after the saturation of performance (termed overlearning) rapidly changed the E/I ratio from higher to lower than baseline. This so-called hyper-stabilization is distinguished from stabilization after typical training and re-stabilization after reactivation, where in both cases, the E/I ratio gradually returned to baseline. Ostry will describe work in which participants learn a novel sensorimotor map by making movements to sounds. MRS is used to track the time course of GABA and glutamate concentration and fMRI is used in the same experimental session to assess learning-related changes in resting-state connectivity. It is seen that over time, decreases in error are related to increases in GABA, suggesting that inhibitory circuits may contribute to stabilizing information that has been learned.

Early Career Award Winner Talk

Thursday, May 3

10:45 – 11:15

Somatosensory feedback for real-world hand control

Andrew Pruszynski, University of Western Ontario

Real world control requires actively using sensory information from the skin and muscles to guide reaching, grasping, and object manipulation. In this talk, I will provide an overview of several ongoing projects that leverage (slightly) more realistic paradigms and experimental manipulations to reveal new insights into these processes. First, I will describe how tactile inputs from the skin can evoke rapid feedback responses that contribute to the online control of object manipulation. Second, I will show that the tactile acuity in the context of such motor control tasks exceeds that for perceptual judgments by nearly an order of magnitude. Third, I will show that, in the context of hand control, spinal stretch reflexes show remarkable sophistication – integrating information across the elbow and wrist joints to operate at the level of the global task goal, to keep the hand on target, regardless of how individual muscles are stretched.

Session 10, Perspective I

Thursday, May 3 11:15 – 12:45

Non-invasive neuromodulation for enhancement of plasticity and sensorimotor performance

Christopher Buneo[1], Vince Clark[2], Steve Helms Tillery[1], Jessica Richardson[2], Jamie Tyler[1]

[1]Arizona State University, [2]University of New Mexico

Recent regulatory developments and scientific advances have spurred an expansive growth of research aimed at discovering new methods of nerve and brain stimulation for enhancing plasticity and sensorimotor function in healthy human subjects and for treating various neurological disorders. For example, transcutaneous electric nerve stimulation of the trigeminal, vagal, and other craniocervical nerves has been shown to safely induce plasticity in healthy humans and provide therapeutic benefits for the treatment of headache, depression, PTSD, and other disorders. Similarly, in the sensorimotor realm, low-level electrical and mechanical stimulation delivered to peripheral nerves has been shown to improve the control of body, arm and leg movements in neurologically intact human subjects as well as those with impaired neurological function due to aging, diabetes and various neurological disorders. In this perspective panel we will review recent findings on the use of non-invasive neuromodulation for enhancing plasticity and sensorimotor performance including current controversies and speculation on the outlook for future clinical applications and research directions. Novel applications of neuromodulation in both the cognitive and sensorimotor domains will be addressed, with an emphasis on cranial nerve stimulation and brain stimulation delivered via TMS and tDCS. The use of these various noninvasive methods will be discussed in the context of both neurological rehabilitation and human performance enhancement in the athletic, healthcare, military, and industrial settings.

Session 12, Panel VI

Friday, May 4 08:00 - 10:15

Fast but smart enough to teach: rapid sensory feedback to guide motor learning

Hongchul Sohn[1], Frédéric Crevecoeur[2], Chao Gu[3], David Franklin[4], Aiko Thompson[5]

[1]Northwestern University, [2]Université catholique de Louvain, [3]University of Western Ontario, [4]Technical University of Munich, [5]Medical University of South Carolina

Can a mere "reflex" shape motor learning? The traditional view that rapid, involuntary, sensory-evoked motor responses are stereotyped has changed. We now appreciate the flexibility of these rapid feedback pathways, which are able to process sensory information and adapt motor commands online in ~100ms to provide flexible, task-dependent control of movement. Recent evidence suggests that this sensory-driven rapid adaptation can also drive motor learning, potentially providing a key mechanism for motor skill acquisition. However, its robustness and relevance to the acquisition of novel skills have yet to be confirmed. This session will address recent work in this area, attempting to explore the following questions: What adaptive changes occur in the rapid feedback pathways during motor learning? Can such changes signify the mechanism underlying the learning process? Should the function of these pathways be the target for training or intervention? The panel will address these questions from multiple perspectives - spanning computational, behavioral, neurophysiological, and clinical. CREVECOEUR will highlight the role of rapid sensory feedback in guiding the initial phase of learning. Focusing on how the brain corrects reaching within a movement to disturbances experienced during early exposure to novel dynamics, he elucidates the processes that render the neural controller insensitive to model errors and deduce internal models in real-time. GU will present rapid visuomotor responses as a neuromuscular signature of the learning process. Specifically, he will demonstrate that the systematic modulation of these responses can be used as a directly assay of the implicit (e.g. error-based), but not the explicit (e.g. aiming strategy), component of learning during visuomotor rotations. FRANKLIN will showcase sophisticated action of rapid feedback pathways in a myriad of learning goals. He will demonstrate how the rapid visuomotor pathway is tuned and fractionated to the complexity of environmental dynamics, reflecting both reactive and predictive components of feedback modulation. He will further discuss the use and modification of the visuomotor feedback in a deafferented participant. Finally, THOMPSON will demonstrate the promising utility of training rapid feedback pathways in restoring motor function. She will show that inducing guided changes in spinal reflex pathways through rewarding a stimulus-triggered EMG response (i.e., operant conditioning) improves impaired locomotion after spinal cord injury. She will discuss potential interaction between rapid task-dependent adaptation and long-term plasticity, and its impacts on functioning of the sensorimotor system. Together, our efforts will shed light on critical neurophysiological mechanisms underlying motor learning, which may be malleable for guiding motor rehabilitation following neurological injuries, or for the acquisition of novel skills in an uninjured population.

Session 13, Individual Presentations III

Friday, May 4 10:45 – 12:45

The nervous system activates muscles to minimize internal joint stresses: evidence from quadriceps muscle activations during motor adaptation in the rat

Cristiano Alessandro[1], Filipe Barroso[1], Qi Wei[2], Yasin Dhaher[3], Thomas Sandercock[1], Dinesh Pai[4], Matthew Tresch[1]

[1]Northwestern University, [2]George Mason University, [3]Shirley Ryan AbilityLab, [4]University of British Columbia

Although many motor control studies consider how the CNS activates muscles to achieve task goals, muscles also act on variables characterizing the state of internal joint variables such as bone contact stresses or ligament strains. We are examining whether the CNS actively regulates these internal joint variables during behavior, evaluating the hypothesis that the CNS chooses muscle activations to minimize joint injury while achieving task goals. We consider this hypothesis in the context of the neural control of quadriceps muscles during locomotion in rats. We first characterized the action of quadriceps muscles on both task and internal joint variables, showing that although vastus lateralis (VL) and vastus medialis (VM) have identical actions on aggregate joint torques (task variables), they have opposing actions on mediolateral patellar forces (internal joint variables). During locomotion we found that VM and VL activations are strongly correlated. The correlation of VM and VL to quadriceps muscles with minimal mediolateral forces (rectus femoris, RF; vastus intermedius, VI) was considerably weaker. These observations are consistent with the hypothesis that the CNS coordinates muscles to minimize net mediolateral forces on the patella, thereby avoiding potential cartilage degradation and injury. To further evaluate this hypothesis we performed perturbation experiments, examining whether neural adaptations strategies reflect control of internal joint variables. We first examined adaptation following selective paralysis of VL. If the CNS only regulated task performance, animals might compensate for VL paralysis by increasing the activation of VM since VM and VL produce identical joint torques. However, increased VM activation will cause unbalanced mediolateral patellar forces. If the CNS regulated internal joint variables, then it might compensate for VL paralysis by increasing activation of RF which has negligible mediolateral patellar forces. We found that animals restored task performance by preferentially increasing activation of RF, consistent with the hypothesis that the CNS regulates internal joint variables. In a second set of perturbation experiments, we examined how animals adapt following application of a lateral force to the patella by placing a spring between screws inserted into the patella and the lateral femur. We found that animals compensated for this spring by altering the ratio between VM and VL so that the activation of VM was increased relative to the activation of VL. This adaptation is consistent with the neural control of internal joint variables, acting to minimize net mediolateral forces. Further, we found that the ratio between VM and VL was altered in the opposite direction after the spring was detached, again suggesting that the CNS regulates mediolateral patellar forces. These experiments provide strong support for the hypothesis that the CNS actively regulates internal joint variables during behavior, suggesting that these variables should be considered in studies investigating the neural control of movement. In future research we will use the results of these behavioral experiments to identify sensory and spinal interneuronal systems underlying the neural control of these internal joint variables.

The molecular engram of procedural motor skill memories resides in layer 5 of the primary motor cortex

Joseph Francis[1], Peng Gao[1]

[1]University of Houston

Procedural motor learning and memories, such as those associated with learning to ride a bike, are thought to be supported by the reorganization and plasticity of the sensorimotor cortex (S1, M1). Utilizing a rodent reach to grasp task, several studies have shown that procedural learning is accompanied by enhanced synaptic strength and structural modification in the primary motor cortex (M1) at distinct layers (e.g. layers II/III and V). However, an investigation that causally links these changes with synaptic molecular machinery and behavior has been elusive. This study aims to fill this gap in our current knowledge by tracking layer specific changes in a key molecule, PKMζ, that has been shown necessary and sufficient for the maintenance of long-term potentiation (LTP), in S1 and M1. In addition, we correlate the changes in PKMζ with changes in task performance. We show that PKMζ levels decrease in Layers II/III of S1 during an early pause in performance gains on day 3 of training. Subsequently, PKMζ levels increase in S1/M1 layers II/III and V as performance improves to an asymptote on day 9, and, after training ends, the increase persists for more than 1 month in M1 layer V. Lastly, we utilized genetic and pharmacological methods to causally perturb PKMζ during and after learning, which slowed the memory formation and weakened its maintenance, but didn't change the asymptotic level of task performance. Blocking PKMζ activity erased sensorimotor memories that were maintained without reinforcement after a consolidation window of greater than 48 hrs. Thus, PKMζ sustains the molecular engram for motor memories maintained without practice within M1 layer V.

Divisively normalized integration of visual and proprioceptive motor memories for motor adaptation

Takuji Hayashi[1], Yutaro Kato[2], Daichi Nozaki[2]

[1]Tokyo University of Agriculture and Technology, [2]The University of Tokyo

Motor adaptation is driven by a discrepancy between the actual and predicted sensory feedbacks (i.e., sensory prediction error). Both vision and proprioception could contribute to the computation of the sensory prediction error, but the manner via which the sensory information of these different modalities are integrated and utilized for motor adaptation is still under debate. We aimed to clarify the way of integration by examining single-trial motor adaptation during a reaching task (N = 10). In perturbation trials, we interleaved one of the 35 combinations of the directional errors of the cursor (±45°, ±30°, ±15°, and 0°; visual error: VE) and those of the hand (±30°, ±15°, and 0°; proprioceptive error: PE) using the force channel method. In the subsequent probe trials, we measured the lateral forces against the force channel (aftereffect). Either VE or PE induced the aftereffect, but the magnitude was not linearly increased with the size of VE or PE, which was consistent with the one reported in previous studies (Wei and Kording, JNP, 2009; Marko et al., JNP, 2012). Most notably, we observed a complicated pattern of the aftereffects when both VE and PE were simultaneously imposed. For example, the aftereffects were suppressed when the VE and PE were imposed in the opposite direction: the aftereffect to -15° VE was suppressed when a +30° PE was additionally applied. In contrast, the aftereffects were not enhanced when the PE and VE were imposed in the same direction: the aftereffect to -15° VE remained almost unchanged even when -30° PE was additionally applied. To our knowledge, previous computational models could not reproduce the results. Recent studies proposed that the sensory information of different modalities could be integrated according to the divisive normalization (Ohshiro et al., Nat Neurosci, 2016). We found that this model [aftereffect = (wvv + wpp) / (σ + v2 + p2), where v and p are VE and PE, respectively, and wv, wp, and σ are constant] satisfactorily reproduced the complicated pattern of aftereffect. A further question is one regarding the stage where the multisensory integration occurs. One idea is that a single motor memory is updated according to the error obtained via the integration of vision and proprioception. Alternatively, the memory for each modality is updated independently and the integration occurs at the output stage. Fourteen participants received the gradually increasing VE and PE in the opposite directions during the reaching movements. The two models predict different trial-dependent pattern for the aftereffect during the following washout phase. The former model predicts the monotonic decay of the aftereffects, while the latter model predicts the emergence of the aftereffects if the time constants of decay for both memories are different. Although the aftereffects were not significantly biased in either direction at the first washout trial, significant aftereffects emerged afterward. These results support the memory integration model and that the visual motor memory has a relatively fast time constant than the proprioceptive motor memory.

Cortical control of vigor, but not timing or direction, in a center-out reach task in mice

Teja Pratap Bollu[1], Samuel Whitehead[1], Itai Cohen[1], Jesse Goldberg[1]

[1]Cornell University

An arm in motion can sweep through a continuum of possible trajectories, making behavioral space intractably high-dimensional for motor control. One solution is to construct movement from a discrete set of elementary building blocks, or motion primitives. Primate arm trajectories are readily decomposable into a sequence of primitives but it remains unclear how primitives are initiated, shaped and sequenced. Although full kinematic details of limb motion can be decoded from motor cortical activity, the function of motor cortex remains unclear, in part because precise neural circuit manipulation remains difficult in primates. To leverage the genetic tractability of the mouse model system, we designed ultra-low torque touch-sensing joysticks that resolve mouse forelimb kinematics with micron-millisecond spatiotemporal resolution. We used a fully-automated homecage system to train mice in a center-out reach task in which mice had to hold their right forelimb still in an inner radius (2 mm) for 100 milliseconds prior to executing a fast, outward reach (>4 mm) to learned targets. Mice learned to accomplish the task by producing trajectories initiated with decamicron-scale micromovements (to satisfy the hold-still criterion) followed by a fast, millimeter-scale outward reaches. Algorithms previously used in primates were effective in decomposing hundreds of thousands of mouse forelimb trajectories into millions of kinematic primitives that, because of the hold-still and reach task components, exhibited speeds (1 - 100 mm/s) and distances (0.01 - 1 mm) spanning orders of magnitude. We next used closed-loop, joystick contact-triggered photoinhibition in VGAT-Chr2-EYFP mice to test the role of motor cortex in initiating, shaping, and sequencing primitives into a trajectory. Inactivation of contralateral caudal forelimb area (CFA CL) reduced trajectory peak speed and displacement. CFA CL inactivation also reduced the peak speed and distance of primitives, independent of whether they were produced during hold-still (decamicron) or reach (millimeter) components of the task. Surprisingly, CFA CL inactivation did not affect reach direction or variability, and also did not affect the durations of primitives. Together these data demonstrate a role of cortex in invigorating movement primitives, independent of their amplitude. They also suggest a primary role for subcortical circuits in reach direction and in patterning motor primitives during internally generated, un-cued movements in mice.

The effects of sensory matching errors in motor control

Irene Kuling[1], Eli Brenner[1], Jeroen Smeets[1]

[1]Vrije Universiteit, Amsterdam

People make systematic errors when matching the location of an unseen index finger with the location of the index finger of the other hand, or with the location of a visual target. In previous studies we found that these visuo-proprioceptive matching errors are influenced by skin stretch manipulations [1], but resistant to force manipulations [2, 3]. Now, I will discuss our recent experiments about the consistency of these idiosyncratic sensory matching errors and the implications of these sensory matching errors in motor control tasks. First, we investigated whether these idiosyncratic visuo-proprioceptive and proprioceptive-proprioceptive matching errors are consistent over time. In a reaching task, participants had to reach for either visual targets or proprioceptive targets without any feedback except for their own proprioception with their unseen hand and without any (visual) feedback. This was repeated within each session and in five additional identical sessions. There were fixed time intervals between the sessions from 5 hours up to 24 days. To quantify the consistency of the matching errors between the sessions we developed a 'consistency value', which takes into account both the magnitude and the direction of the matching errors that are compared. The results show that the individual systematic errors were consistent throughout the two-month period of the experiment, although they differed between subjects [4]. Second, to see whether these errors reflect sensory biases, we designed sets of tasks that involved the same matching configurations, but different actions to reach this configuration. For example, we compared matching errors when moving with the unseen index finger to a visual target, with matching errors when moving a visual target to the unseen index finger. We found that the matching errors are not invertible. Furthermore, moving both index fingers sequentially to the same visual target results in a different mismatch between the hands than directly matching the two index fingers [5]. The matching errors are thus not the direct result of sensory biases. Third, we asked participants to reach towards the closer of two visual targets from a varying unseen starting position. We found that the visuo-proprioceptive matching errors are reflected in the action decision, showing that these mismatches are not specific to the execution of a specific task, but the result of a more general sensorimotor process. 1. Kuling, I.A., et al., Front Psychol, 2016. 2. Kuling, I.A., et al., PLoS One, 2013. 3. Kuling, I.A., et al., Exp Brain Res, 2015. 4. Kuling, I.A., et al., Acta Psychol, 2016. 5. Kuling, I.A., et al., Exp Brain Res, 2017.

Primary motor cortex (M1) encodes a value function consistent with reinforcement learning

Venkata S Aditya Tarigoppula[1], John Hessburg[2], John Choi[3], David McNiel[2], Brandi Marsh, Joseph Francis[1]

[1]University of Houston, Cullen School of Engineering, [2]SUNY Downstate Medical Center, [3]New York University

Reinforcement learning (RL) theory provides a simple model that can help explain many animal behaviors. A key component of RL is the value function, which captures the expected, temporally discounted reward, from a given state. The value function can also be modified by the animal's knowledge and certainty of its environment. Here we show that the motor cortex (M1) displays important components of the temporal difference (TD) RL model while monkeys performed various classical/operant conditioning tasks. Contralateral and ipsilateral M1 responded to the reward delivery in sessions with chance trial value predictability, which is the predictability of the next trials value, and consequently the expected reward value. Trial value predictability in a session was controlled by a combination of the total number of rewarding vs. non-rewarding trials, bias, and the sequence structure of trial values presented in a session. Contralateral and ipsilateral M1 shifted their expected reward-related responses earlier in a trial, becoming increasingly predictive of the expected reward, irrespective of the presence or absence of a reward-predictive cue, in sessions with trial value predictability. An increase in the percentage of contralateral and ipsilateral M1 units encoding the expected reward value was observed during and after conditioning. M1 lost and regained its ability to encode the expected reward accurately during reversal learning where an established cue-reward association was reversed. M1 also encoded the reward prediction error observed either in the first few trials following the cue-reward association reversal or in catch trials where the expected reward was omitted. A reward prediction error occurs when there is a discrepancy between the value function and actual reward, and this error is used to drive learning in TDRL. Multiple levels of reward were also encoded in M1. This is observed in tasks performed manually or observed passively. Reward-related dynamics in M1 were also consistent irrespective of whether the task being performed was center-out reaching or a grip force task. The Microstimulus Temporal Difference RL model, reported to accurately capture RL related dopaminergic activity, extends to account for the M1 reward-related neural activity. We propose that the reward signal in M1 is reminiscent of the value function defined under the Temporal Difference Reinforcement Learning model.

Session 15, Panel VII

Friday, May 4 14:45 - 16:45

Brain mechanisms of motor learning in health and disease

Tibor Hortobagyi[1], Kelly Berghuis[1], Brad King[2], Beth Fisher[3], Brita Fritsch[4], Rachael Seidler[5]

[1]University Medical Center Groningen, [2]Katholieke Universiteit Leuven, [3]University of Southern California Los Angeles, [4]Albert-Ludwigs-University, [5]University of Florida

Panel presentation, 'Brain mechanisms of motor learning in health and disease', will provide a state of the art update on advances in motor learning in animals, healthy humans, and individuals needing motor rehabilitation. After an introduction of the basic features of motor learning, Ms. Berghuis will discuss that while healthy older adults are capable of learning a novel visuomotor skill, they are less effective in retaining and retrieving the stored memory traces. Brain excitability indexed by TMS can be motor task- but not age-dependent and fMRI data favor the compensation-related utilization of neural circuits hypothesis in older adults (CRUNCH). In other models of motor learning, healthy older compared with younger adults reveal deficits in skill acquisition, consolidation, and retention. Using multimodal neuroimaging, including task-based activity, resting state functional connectivity and neuro-metabolic data, Dr. King will discuss whether sleep and non-invasive brain stimulation are viable and effective avenues to enhance motor learning and consolidation processes in both healthy and pathological populations. The process of motor learning can be noninvasively modulated by application of weak electrical currents to the brain. Dr. Fritsch will provide insights into the basic mechanisms of neuromodulation tDCS with emphasis on neuroplasticity in the motor system. The strengths and weaknesses of translation from rodent experiments to humans will be covered. Finally, Prof. Fisher will discuss how practice variables affect motor learning, behavioral improvements, neuroplasticity, and brain repair in individuals with neuropathology. She will focus on motor learning practice variables known to facilitate neuroplasticity and functional recovery in individuals with brain injury from a single event such as stroke or in neurodegeneration. The General Discussion will include but not limited to addressing the following questions: 1. Is there a universal neural substrate that mediates motor skill acquisition, consolidation, retention, and retrieval generated if not by all but by most models of motor learning? 2. Do behavioral improvements produced by motor practice correlate with changes in focal excitability and network activation? 3. How do non-invasive brain stimulation methods enhance motor learning? 4. Are neuromodulation-enhanced motor memory traces as stable and resistant to interference as those produced without neural enhancement? 5. Does the method of neuromodulation that is most effective in producing motor learning, differ between patient groups? 6. Do specific clinical conditions affect how stable and resistant motor memory traces are against interference?

Distinguished Career Award Winner Talk

Friday, May 4 16:45 – 18:00

Shining light in the dark basement: The basal ganglia in action

Ann Graybiel, McGovern Institute for Brain Research at the Massachusetts Institute of Technology

The basal ganglia have long been known by clinicians to be important in the genesis of extrapyramidal motor disorders, but these deep-lying structures of the forebrain were relatively neglected by basic scientists, due to their physical inaccessibility. A revolution in our understanding of these structures now is on-going. Dopamine-containing neurons, discovered by Schultz and Romo to signal unexpected rewards and reward-related cues (reward prediction errors), now are being found to become active just before movements, as either drivers or motivation-related modulators of movement initiation. The direct and indirect basal ganglia pathways, proposed as go/no-go systems for movement control, are seen as co-active regulators of movement, likely aligning with the pioneering hypothesis put forward by Mink and Thach. Frequency-specific oscillatory activities in basal ganglia networks are now seen as hallmarks of dysfunction (and increasingly, of function) of basal ganglia circuits. Yet the question of why we move or do not move has remained a mystery. We work on this mystery in our laboratory. We have identified major circuits leading from prefrontal cortical regions related in human to mood and affect to specialized zones in the striatum called striosomes (striatal bodies) and then to the dopamine-containing neurons of the substantia nigra and to the lateral habenula, which itself can modulate the dopamine and serotonin systems. We are finding that these circuits are differentially activated in relation to cost-benefit decisions about whether to act or not—whether to approach or to avoid offers—when the offers combine rewarding and aversive options. These experiments capitalize on modified versions of approach-avoidance tasks initially designed to study anxiety and depression in humans. By manipulating these striosome-related circuits, we can strikingly modify the amounts of approach and avoidance behavior. We have found that these circuits are also related to repetitive, stereotyped movements, hallmarks of some neuropsychiatric disorders and of the results of exposure to chronic stress. The functions of these circuits could have powerful effects on the control of action in health and disease.

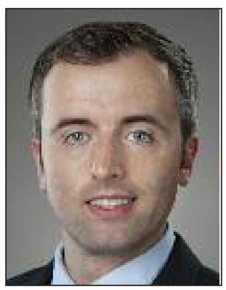
NCM Scholarship Winners 2018

New investigators and faculty are essential for the future of any field of scientific inquiry. NCM has historically encouraged conference participation by graduate students and post-doctoral fellows. The scholarship program is designed to provide partial support for them to participate in the conference and is open to student and post-doc members in good standing. Our scholarship program is funded through the support of our sponsors and through an NIH grant for 2018.

Marc Bächinger
ETH Zürich

Marc Bächinger studied Neuroscience at ETH Zürich. He recently obtained his PhD at the Neural Control of Movement Lab where he investigated different interventions to modulate activity within the sensorimotor system using a combined tACS-fMRI approach. Since January 2018 he is continuing his research in the lab as a postdoc.

Michael Berger
University of Gottingen

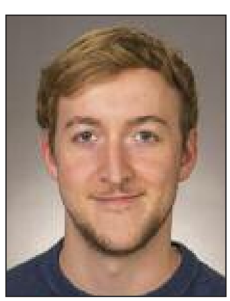


I am working in the lab of Alexander Gail at the German Primate Center and recently defended my PhD. My research focuses on motor-goal encoding beyond the reachable distance and primate neuroscience without applying physical constraints. Also, I am interested in NHP animal welfare and science communication regarding animal research.

Kelly Berghuis
University of Groningen

I am a PhD student at the University of Groningen, University Medical Center Groningen in The Netherlands, and I am focusing on the neuronal mechanisms of motor learning in healthy aging. At the meeting, I will give a symposium talk and poster presentation about my project.

Kyle Blum
Georgia Tech/Emory University



Kyle Blum is an NIH NRSA predoctoral fellow in Biomedical Engineering at Georgia Tech and Emory University. His long term scientific goals involve understanding the mechanisms – at multiple scales ranging from individual receptors to cortex - underlying encoding information about our bodies and surroundings, and how they influence movement.

Tejapratap Bollu
Cornell University

I am a PhD candidate in Jesse Goldberg's lab. I study both how and why animals move the way they do, i.e. both the neural and evolutionary basis for movement. I study these questions by building novel behavioral paradigms and assays for Mice and Honey Bees.

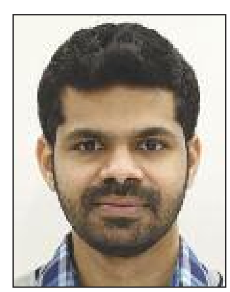
Raeed Chowdhury
Northwestern University

Raeed is currently a PhD candidate in Lee Miller's lab at Northwestern University. He is interested in the neurophysiology of proprioception, with a particular interest in how it relates to motor control. Currently, he is studying how neurons in primary somatosensory cortex of monkeys represent reaching movements.

Nienke Debats
Bielefeld University

I am a postdoctoral researcher interested in the influence of active movement on perception. Currently, I study sensory integra-tion in a basic cursor- control reaching task, aiming to gain understanding of the causal inference process that underlies the integration. In my work I combine kinematic analysis, biomechanics, psychophysics, and computational modelling.

Naveen Elangovan
University of Minnesota



Naveen Elangovan is a postdoctoral researcher in University of Minne-sota. He is a trained physical therapist from India. He has an earned doctorate in Neural Control and Biomechanics. His research interests include proprioceptive learning, sensorimotor integration, movement disorders, stroke, and robotic rehabilitation.

Chao Gu
Western University

I am currently a PhD candidate in the lab of Dr. Brian Corneil at the University of Western Ontario. My research focuses on under-standing how the brain transforms visual information into motor commands, specifically by examining the sensorimotor properties of visual reflexes at the motor periphery.

Takuji Hayashi
Tokyo University of Agriculture and Technology

I earned Ph.D. under the supervision of Daichi Nozaki at the University of Tokyo, and I am a postdoc at Tokyo University of Agriculture and Technology with Ken Takiyama. My interest is the computational mechanisms of motor control and learning, especially of multisensory integration for motor adaptation.

Sanne Kikkert
ETH Zürich

Sanne Kikkert completed her PhD in Clinical Neurosciences at the University of Oxford in 2018. She is currently a postdoc at the Neural Control of Movement lab at ETH Zürich and uses neuroimaging to study how organisation in the somatosensory processing stream changes or persists following major sensory input loss.

Irene Kuling
Vrije Universiteit Amsterdam

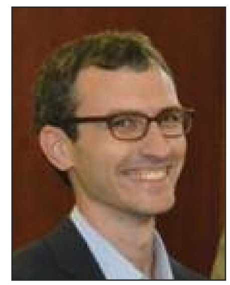
Irene A. Kuling received the Ph.D. degree in visuo-haptic perception from Vrije Universiteit Amsterdam, Netherlands, under supervision of Prof. Jeroen Smeets. Currently, she is working as a postdoc in the lab of Prof. Philippe Lefèvre at Université catholique de Louvain, Belgium. Her research interests include human perception, haptics, and motor control.

Yi-Ling Kuo
University of Southern California

Yi-Ling Kuo, a PhD candidate in Beth Fisher's lab at University of Southern California. Her research focuses on the contribution of interhemispheric inhibition to unimanual and bimanual coordination in skilled musicians. She aims to understand neuroplasticity associated with advanced skills, and the translation to patients with impaired hand motor control.

Kevin Mazurek
University of Rochester

Kevin Mazurek received his B.S. from Brown University (2008) and Ph.D. from Johns Hopkins University (2013), both in Electrical Engineering. He is a postdoctoral fellow in Neurology at the University of Rochester, studying intracortical microstimulation delivered instructions. His career goal is to develop restorative solutions that bypass damaged neural pathways.



Hongchul Sohn
Shirley Ryan Ability Lab

Hongchul Sohn is an NRSA postdoctoral fellow at Northwestern University. He received his PhD in Mechanical Engineering from Georgia Institute of Technology in 2015. His research focuses on sensorimotor integration underlying human motor control and learning, with the long-term goal of developing tailored interventions for individuals with neurological disorders.

Erik Summerside
University of Colorado, Boulder

Erik is a doctoral candidate working with Dr. Alaa Ahmed at the University of Colorado. His interests lie in exploring ways to promote movement in humans. He examines how the brain represents effort, how reward discounts effort, and how interactions of these costs and benefits explain movement preferences across populations.

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All posters will be located in the Tewa Ballroom

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The poster numbers are divided first by session, then by theme and finally with a unique number.

Session – Theme – Board Number (ex. 1-A-1).

Please note that posters with an uneven end number (1-A-1, 1-A-3, etc) will be presented during the first hour of the poster session. Posters with an even end number (1-A-2, 1-A-4, etc) will be presented in the second hour of the poster session.

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Poster Sessions | Authors, Titles and Affiliations

The Society for the Neural Control of Movement is pleased to present a wide range of current research through the poster sessions. The posters have been divided over two sessions, each on display for two days.

Session 1:	Tuesday May 1:	08:00 – 17:00
	Wednesday May 2:	08:00 – 17:15
Session 2:	Thursday May 3:	08:00 – 14:15
	Friday May 4:	08:00 – 14:45

The poster numbers are divided first by session, then by theme and finally with a unique number.

Session – Theme – Board Number (ex. 1-A-1).

Please note that posters with an uneven end number (1-A-1, 1-A-3, etc) will be presented during the first hour of the poster session. Posters with an even end number (1-A-2, 1-A-4, etc) will be presented in the second hour of the poster session.

Themes

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

Poster Session 1

Tuesday May 1 & Wednesday May 2

Posters are listed by theme.

All posters will be located in the Tewa Room.

A - Control of Eye & Head Movement

1-A-1 Oculomotor abnormalities in mtbi

John Anderson[1]

[1]Minneapolis VA Health Care System - University of Minnesota

1-A-2 The role of superior parietal-occipital cortex in human reach-to-grasp movement: TMS study

Mariusz Furmanek[1], Mathew Yarossi[1], Luis Schettino[2], Sergei Adamovich[3], Eugene Tunik[1]

[1]Northeastern University, [2]Lafayette College, [3]New Jersey Institute of Technology

1-A-3 Role of the superior colliculus-pulvinar pathway in blindsight

Tadashi Isa[1], Masaharu Kinoshita[2], Rikako Kato[1], Kenta Kobayashi[3], Kaoru Isa[1], Kazuto Kobayashi[4], Hirotaka Onoe[1]

[1]Kyoto University, [2]Hirosaki University, [3]National Institute for Physiological Sciences, [4]Fukushima Medical University

1-A-4 Head movements towards spatiotemporally separated sound sources

Guus Bentum[1], John van Opstal[1], Marc van Wanrooij[1]

[1]Donders Institute Nijmegen, Radboud University

1-A-5 The activity of simple and complex spikes in the vestibular Purkinje cells is attenuated during self-generated head movements

Omid Zobeiri[1], Kathleen Cullen[1]

[1]Johns Hopkins University

B – Fundamentals of Motor Control

1-B-6 Dissociation between temporal expectancy and spatial precueing in the neural dynamics of goal-directed movement preparation

Cesar Canaveral[1], Frederic Danion[2], Pierre-Michel Bernier[1]

[1]Universite de Sherbrooke, [2]CNRS & Aix-Marseille University

1-B-7 Neurophysiological correlates of speech motor control

Adithya Chandregowda[1], Yael Arbel[2], Emanuel Donchin[3]

[1]University of South Florida, Mayo Clinic, [2]Massachusetts General Hospital Institute of Health Professions, [3]University of South Florida

1-B-8 The cost to move affects gaze-limb coordination

F. Javier Domínguez-Zamora[1], Daniel Marigold[1]

[1]Simon Fraser University

1-B-9 Plan, Initiate, Execute: The invigorating role of the motor thalamus

Matt Gaidica[1], Daniel Leventhal[1], Amy Hurst[1], Chris Cyr[1]

[1]University of Michigan

1-B-10 Neural and behavioral signatures of motor skill in the wild

Shlomi Haar[1], Ines Rito-Lima[1], Pavel Orlov[1], Aldo Faisal[1]

[1]Imperial College London

1-B-11 Sensorimotor oscillatory power shapes rhythmic fluctuations in human corticospinal excitability

Sara Hussain[1], Leonardo Claudino[1], Marlene Boenstrup[1], Gina Norato[1], Christoph Zrenner[2], Ulf Ziemann[2], Ethan Buch[1], Leonardo Cohen[1]

[1]National Institutes of Health, [2]University of Tuebingen

1-B-12 Motor cortical changes in preparation for self-paced actions investigated with combined Transcranial Magnetic Stimulation and Electroencephalography

Jaime Ibanez[1], John Rothwell[1], Lorenzo Rocchi[1], Ricci Hannah[1]
[1]University College London

1-B-13 Transcranial direct current stimulation (tDCS) of SMA complex impacts the effectiveness of interleaved and repetitive practice schedule

Taewon Kim[1], David Wright[1]
[1]Texas A&M University

1-B-14 Long-latency reflexes to on-axis and off-axis displacements increase with the target approach consistent with optimal feedback control

Isaac Kurtzer[1], Frederic Crevecoeur[2], Puneet Cheema[1], Ryan Antonawich[1], Tetsuro Muraoka[3]

[1]New York Institute of Technology - College of Osteopathic Medicine, [2]Université Catholique de Louvain, [3]Nihon University

1-B-15 Revisiting the mesencephalic locomotor region: An interface between the basal ganglia and the spinal cord

Daniel Dautan[1], Juan Mena-Segovia[1]
[1]Rutgers University

1-B-16 Causal relationships between EMG, EEG and fNIRS during isometric hand contractions.

Pablo Ortega[1], Shlomi Haar[1], Aldo Faisal[1]
[1]Imperial College London

1-B-17 Precisely estimating neural population dynamics in motor cortex using deep learning

Chethan Pandarinath[1], Daniel O'Shea[2], Jasmine Collins[3], Rafal Jozefowicz[3], Sergey Stavisky[2], Jonathan Kao[2], Eric Trautmann[2], Matthew Kaufman[2], Stephen Ryu[2], Leigh Hochberg[4], Jaimie Henderson[2], Krishna Shenoy[2], Laurence Abbott[5], David Sussillo[3]

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1-B-18 Temporal dynamics of reach-to-grasp: Evidence for sequential encoding.

Adam Rouse[1], Marc Schieber[1]
[1]University of Rochester

1-B-19 Co-contraction improves control through neural feedback not muscle stiffness

Christopher Saliba[1], Michael Rainbow[1], William Selbie[2], Kevin Deluzio[1], Stephen Scott[1]
[1]Queen's University, [2]HAS Motion

1-B-20 Neural substrate for learning novel sensorimotor maps

Floris van Vugt[1], Yujia Zeng[1], David Ostry[1]
[1]McGill University

1-B-21 Modeling neural population dynamics in motor cortex leads to improved kinetic decoding in unstructured motor task

Lahiru Wimalasena[1], Anil Cherian[2], Lee Miller[2], Chethan Pandarinath[1]

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C – Posture & Gait

1-C-21 Adaptation to real-life external environments immersive virtual reality: a pilot study

Tanvi Bhatt[1], Shivani Paralkar[1], Gonzalo Varas[1], Wang Jay[1]

[1]University of Illinois at Chicago

1-C-22 Impaired directional perception of whole-body perturbations in people with parkinson's disease may contribute to balance impairment

Sistania Bong[1], J. Lucas McKay[1], Stewart Factor[2], Lena Ting[1]

[1]Emory University and Georgia Tech, [2]Emory University School of Medicine

1-C-23 Identifying gait phase transitions and perturbed gait dynamics using switching linear dynamical models

Luke Drnach[1], Irfan Essa[1], Lena Ting[2]

[1]Georgia Institute of Technology, [2]Emory University & Georgia Tech

1-C-24 Longitudinal tracking of muscle synergies of infants during the critical months of learning to walk

Sophia C.W. Ha[1], Zoe Y.S. Chan[2], Janet H. Zhang[2], Roy T.H. Cheung[2], Vincent C.K. Cheung[1]

[1]The Chinese University of Hong Kong, [2]The Hong Kong Polytechnic University

1-C-25 Muscle synergies during cat locomotion: effects of epidural spinal stimulation on locomotor CPG

Alexander Klishko[1], Sergey Markin[2], Ilya Rybak[2], Pavel Zelenin[3], Yury Gerasimenko[4], Pavel Musienko[5], Tatiana Deliagina[3], Boris Prilutsky[1]

[1]Georgia Institute of Technology, [2]Drexel University College of Medicine, [3]Karolinska Institutet, [4]University of California, Los Angeles, [5]Pavlov Institute of Physiology

1-C-26 How to define a person walking and running style?

Juan Mantilla[1], Danping Wang[2], Junhong Wang[2], Jiuwen Cao[1], Anke Xue[2], Pierre-Paul Vidal[2]

[1]Université Paris Descartes, [2]Hangzhou Dianzi University/Université Paris Descartes

1-C-27 Cerebral glucose metabolic abnormalities in Parkinson's Disease with freezing of gait during complex walking

Trina Mitchell[1], Alexandra Potvin-Desrochers[1], Oury Monchi[2], Alexander Thiel[1], Caroline Paquette[1]

[1]McGill University, [2]University of Calgary

1-C-28 Task difficulty-related modulation of peroneus longus neural excitability during standing in young adults

Tulika Nandi[1], Claudine J Lamoth[1], Helco van Keeken[1], Lisanne M Bakker[1], George Salem[2], Beth Fisher[2], Tibor Hortobágyi[1]

[1]University Medical Center Groningen, University of Groningen, [2]University of Southern California

1-C-29 Sensory integration for control of frontal plane body orientation during stance and gait in younger and older adults

Robert Peterka[1], Meghan Stansell[1]

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1-C-30 Dissecting changes in perception following locomotor adaptation

Cristina Rossi[1], Kristan Leech[1], Amy Bastian[1]

[1]Johns Hopkins University

1-C-31 A method for identifying impending postural instability and the responsible mechanisms

Kyle Siegrist[1], James Chagdes[1]

[1]Miami University

1-C-32 Consequences matter when performing a behavior with multiple goals

Kara Simon-Kuhn[1], Jeffrey Haddad[1], Jessica Huber[1]

[1]Purdue University

1-C-33 Cortical dynamics of compensatory balance control

Teodoro Solis-Escalante[1], Joris Van der Cruijsen[2], Digna De Kam[1], Joost Van Kordelaar[3], Alfred Schouten[2], Vivian Weerdesteyn[1]

[1]Radboud University Medical Centre, [2]Delft University of Technology, [3]University of Twente

1-C-34 Examining spatiotemporal and kinematic parameters for backward stepping: Are volitional and reactive step responses different?

Tanvi Bhatt[1], Riddhi Panchal[1], Jay Wang[1]

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1-F-35 Obstacle-induced trip perturbation training: proactive and reactive adaptation to reduce falls in community-dwelling older adults

Yiru Wang[1], Shuaijie Wang[1], Tanvi Bhatt[1]

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D – Integrative Control of Movement

1-D-36 Emotionally reacting to being "off-course": the role of cognitive and limbic circuits during movements in humans

Macauley Breault[1], Pierre Sacré, Matthew Kerr, Matthew Johnson, Juan Bulacio, Jorge González-Martínez, John Gale, Sridevi Sarma[1]

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1-D-37 Time-dependent impact of urgency on corticospinal excitability during action selection

Gerard Derosiere[1], David Thura[2], Simon Van Hemelrijck[1], Julien Grandjean[1], Paul Cisek[2], Julie Duque[1]

[1]Institute of Neuroscience, catholic University of Louvain, [2]Department of Neuroscience, Université de Montréal

1-D-38 Consolidation of human somatosensory memory during motor learning

Juergen Konczak[1], Anna Vera Cuppone[2], Marianna Semprini[2]

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1-D-39 Wild monkeys structure motor variability to maintain a stable bipedal stance while using stone hammers

Madhur Mangalam[1], Robert Rein[2], Dorothy Fragaszy[1]

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1-D-40 Effects of hand prosthesis operational parameters on user performance and cognitive agency

Raviraj Nataraj[1], Aniket Shah[1], Sean Sanford[1]

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1-D-41 Tactile and non-tactile inputs are linearly integrated for the estimation of fingertip distance

Daisuke Shibata[1], Simone Toma[2], Francesco Chinello[3], Marco Santello[2]

[1]University of New Mexico, [2]Arizona State University, [3]University of Siena, Aarhus University

1-D-42 Neuronal activity during action observation and execution in macaque somatosensory cotex

Amit Yaron[1], Tomomichi Oya[2], Joachim Confais[1], Kazuhiko Seki[2]

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E – Disorders of Motor Control

1-E-43 Temporal and spatiotemporal organization of muscle patterns is affected by cerebellar damage

Denise Berger[1], Marcella Masciullo[1], Marco Molinari[1], Francesco Lacquaniti[2], Andrea d'Avella[3]

[1]Fondazione Santa Lucia, [2]University of Rome Tor Vergata, [3]University of Messina

1-E-44 Proprioceptive training can enhance proprioceptive-motor function in people with Parkinson's disease

Naveen Elangovan[1], Paul Tuite[1], Juergen Konczak[1]

[1]University of Minnesota

1-E-45 Integrating data from speech and limb sensorimotor learning tasks in children and adults who stutter

Kwang Kim[1], Ludo Max[1]

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1-E-46 Effects of evoked cutaneous afferents on voluntary reaching movement in patients with Parkinson's Disease

Zixiang Hu[1], Shaoqing Xu[2], Manzhao Hao[1], Qin Xiao[2], Ning Lan[1]

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1-E-47 Impaired motor abilities during prediction in children with autism spectrum disorder

Se-Woong Park[1], Annie Cardinaux[2], Dena Guo[1], Shlomit Ben Ami[2], Leila Denna[2], Pawan Sinha[2], Dagmar Sternad[1]

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1-E-48 Functional connectivity between motor brain areas and basal ganglia in Parkinson's Disease patients with and without freezing of gait.

Alexandra Potvin-Desrochers[1], Trina Mitchell[1], Caroline Paquette[1]

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1-E-49 Comparing upper extremity post-stroke proprioceptive impairment using 3 different methods

Jennifer Semrau[1], Jean-Luc Marnet[2], Stephen Scott[2], Sean Dukelow[1]

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1-E-50 Attacking abnormal arm muscle synergies after stroke using myoelectric computer interface training

Marc Slutzky[1], Goran Tomic[1], Aparna Singh[1], Saad Hameed[1], Ninghe Cai[1], Jinsook Roh[2], Emily Mugler[1]

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1-E-51 Portable, interactive motion-capture device for upper-limb movement rehabilitation: A feasibility study

Won Joon Sohn[1], Terence Sanger[2], Dagmar Sternad[1]

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1-G-52 Rhythmic manipulation of complex objects with nonlinear and linearized dynamics

Won Joon Sohn[1], Rashida Nayeem[1], Ian Zuzarte[1], Neville Hogan[2], Dagmar Sternad[1]

[1]Northeastern University, [2]Massachusetts Institute of Technology

1-E-53 Impairment of human ocular tracking with low-dose alcohol

Terence Tyson[1], Nathan Feick[1], Patrick Cravalho[1], Tiffany Tran[1], Erin Flynn-Evans[2], Leland Stone[2]

[1]San José State University Research Foundation, [2]NASA Ames Research Center

F – Adaptation & Plasticity in Motor Control

1-F-54 Head movement during functional gait assessment predicts clinical measures in vestibular patients

Kathleen Cullen[1], Omid Zobeiri[1], Gavin Mischler[1], Susan King[2], Richard Lewis[2]

[1]Johns Hopkins University, [2]Mass. Eye and Ear / Harvard Medical School

1-F-55 Fatigue induces long lasting changes in motor skill learning

Meret Branscheidt[1], Panagiotis Kassavetis[1], Davis Rogers[1], Martin Lindquist[1], Pablo Celnik[1]

[1]Johns Hopkins University

1-F-56 Repeated bout rate enhancement is elicited by passive finger tapping

Anders Emanuelsen[1], Michael Voigt[1], Pascal Madeleine[1], Ernst Hansen[1]

[1]Aalborg University

1-F-57 Savings in muscle activation patterns during a virtual surgery task

Victor Barradas[1], Toshihiro Kawase[2], Yasuharu Koike[2], Nicolas Schweighofer[1]

[1]University of Southern California, [2]Tokyo Institute of Technology

1-F-58 Stepping in time: exploring locomotor adaptation and learning in persons with ET

Sarah Brinkerhoff[1], Jaimie Roper[1], Benjamin Harrison[2], Chris Hass[2]

[1]Auburn University, [2]University of Florida

1-F-59 Perceived depth modulates visuomotor adaptation

Carlo Campagnoli[1], Jordan Taylor[1]

[1]Princeton University

1-F-60 RoboBird: A passive exo-tendon for guinea fowl

Suzanne Cox[1], Jonas Rubenson[1], Gregory Sawicki[2]

[1]Penn State University, [2]Georgia Institute of Technology

1-F-62 Implicit adaptation is driven by the update of an inverse model, not a forward model

Alkis Hadjiosif[1], Adrian Haith[1]

[1]Johns Hopkins University

1-F-63 Functional vestibular cortical changes with spaceflight

Kathleen Hupfeld[1], Vincent Koppelmans[2], Jessica Lee[1], Nichole Gadd[3], Igor Kofman[3], Yiri De Dios[3], Roy Riascos-Castaneda[4], Jacob Bloomberg[5], Ajitkumar Mulavara[3], Rachael Seidler[1]

[1]University of Florida, [2]University of Utah, [3]KBRwyle Science, Technology and Engineering, [4]University of Texas Health Science Center at Houston, [5]NASA Johnson Space Center

1-F-64 Reorganizing muscle coordination using mental imagery and augmented visual feedback

Shanie Jayasinghe[1], Rajiv Ranganathan[1]

[1]Michigan State University

1-F-65 Use-dependent biases due to movement repetition are small and unaffected by rewards

Hyosub Kim[1], Richard Ivry[1]

[1]University of California, Berkeley

1-F-66 Integration of non-automatic and automatic motor control policies during novel bimanual motor task

Toshiki Kobayashi[1], Shoko Kasuga[1], Junichi Ushiba[1], Satoshi Honda[1], Stephen Scott[2]

[1]Keio University, [2]Queen's University

1-F-67 Unimanual contribution to bimanual coordination in musicians: differential impact of the left and right hands

Yi-Ling Kuo[1], Yannick Darmon[1], Perri Kraus[1], Heather Schlueter[1], Alan Chen[1], Beth Fisher[1]

[1]University of Southern California

1-F-68 Generalization of internal models of limb dynamics

Rodrigo Maeda[1], Tyler Cluff[2], Paul Gribble[3], Andrew Pruszynski[3]

[1]Western University, [2]University of Calgary, [3]University of Western Ontario

1-F-69 Proprioceptive changes associated with complex motor skill learning

Jasmine Mirdamadi[1], Hannah Block[1]

[1]Indiana University Bloomington

1-F-70 Differential involvement of the posterior-parietal cortex in consolidation for procedural and declarative learning

Alexandria Pabst[1], Ramesh Balasubramaniam[1]

[1]University of California, Merced

1-F-71 Implicit adaptation is modulated by task relevance of multiple cursors

Darius Parvin[1], J. Ryan Morehead[2], Kristy Dang[1], Alissa Stover[1], Richard Ivry[3]

[1]University of California, Berkeley, [2]Harvard University

1-F-72 Evidence of mixed reference frame representations for both implicit and explicit learning in a visuomotor adaptation task

Eugene Poh[1], Jordan Taylor[1]

[1]Princeton University

1-F-73 Combining reward and M1 transcranial direct current stimulation enhances the retention of newly learnt sensorimotor mappings

Danny Spampinato[1], John Rothwell[1]

[1]University College London

1-F-74 Lack of generalization between explicit and implicit visuomotor learning

Jinsung Wang[1], Shancheng Bao[1], Grant Tays[1]

[1]University of Wisconsin – Milwaukee

G – Theoretical & Computational Motor Control

1-G-75 The neural substrates of error and success in adaptation to visuomotor rotation

Guy Avraham[1], Anat Shkedy-Rabani[1], Ofer Groweiss[1], Lior Shmuelof[1]

[1]Ben-Gurion University of the Negev

1-G-76 Do neuromechanically-based effort variables represent the metabolic cost of reaching?

Garrick Bruening[1], Alaa Ahmed[2]

[1]CU Boulder, [2]University of Colorado

1-G-77 Elucidating the role of sensorimotor cortex for motor adaptation using hierarchical optimal feedback control theory

Travis DeWolf[1], Mackenzie Mathis[2], Alexander Mathis[3]

[1]Applied Brain Research, [2]Harvard University - University of Tübingen, [3]University of Tübingen - Harvard University

1-G-78 Spatial encoding of reaches in preparatory motor cortical activity

Nir Even-Chen[1], Blue Sheffer[1], Saurabh Vyas[1], Stephen Ryu[1], Krishna Shenoy[1]

[1]Stanford University

1-G-79 Cerebellar activity reflects the attenuation of self-touch

Konstantina Kilteni[1], H. Henrik Ehrsson[1]

[1]Karolinska Institutet

1-G-80 Decomposition of endpoint jerk during arm movements of stroke survivors and unimpaired controls

Jozsef Laczko[1], Lucia Simo[2], Davide Piovesan[3]

[1]Wigner Research Centre for Physics, University of Pecs and Northwestern University, [2]Northwestern University, [3]Gannon University

1-G-81 Towards goal-driven deep neural network models to elucidate human arm proprioception

Pranav Mamidanna[1], Claudio Michaelis[1], Alexander Mathis*[2], Matthias Bethge*[3]

* indicates Co-Senior Authors

[1]University of Tübingen, [2]University of Tübingen - Harvard University, [3]University of Tübingen -- MPI Tübingen

1-G-82 Stability and predictability in the control of dynamically complex objects

Dagmar Sternad[1], Julia Ebert[2], Neville Hogan[3], Salah Bazzi[1]

[1]Northeastern University, [2]Harvard University, [3]Massachusetts Institute of Technology

1-G-83 Cost functions as a language for internal communication in the sensorimotor system

Emo Todorov[1]

[1]University of Washington, Roboti LLC

1-G-84 A predictive framework to indicate task invariance of distal upper limb muscle synergies

Mathew Yarossi[1], Sezen Yağmur Günay[1], Deniz Erdoğmuş[1], Eugene Tunik[1]

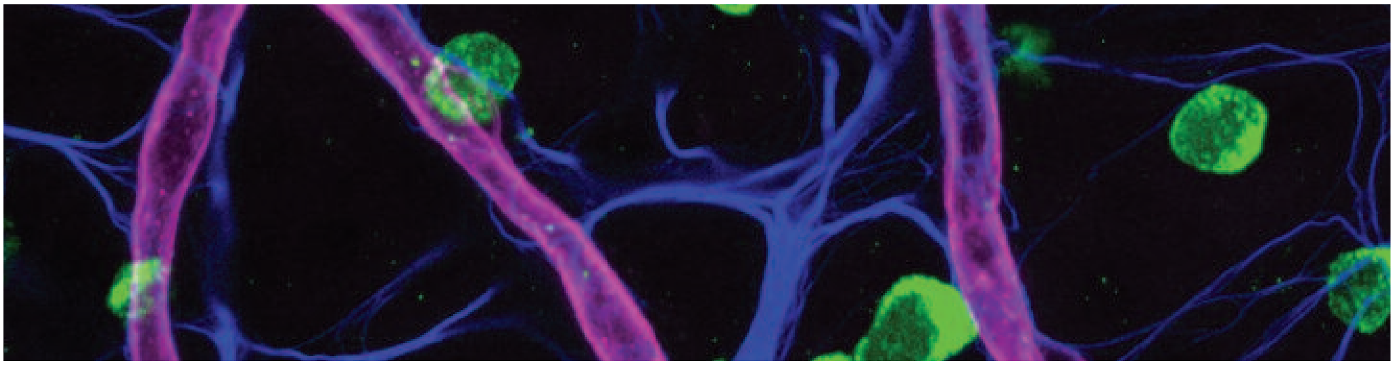
[1]Northeastern University

1-G-85 Throwing is not all about timing: adding noise can enhance timing accuracy

Zhaoran Zhang[1], Abigail Cahill[1], Dena Guo[1], Se-Woong Park[1], Dagmar Sternad[1]

[1]Northeastern University

Notes



Poster Session 2

Thursday May 3 and Friday May 4

Posters are listed by theme.

All posters will be located in the Tewa Room

A - Control of Eye & Head Movement

2-A-1 Use of eye-movements during reproduction of multi-modal self-motion

Jan Churan[1], Anna von Hopffgarten[1], Frank Bremmer[1]

[1]Philipps-Universität Marburg

2-A-2 Bilateral subthalamic nucleus deep brain stimulation increases fixation instability: evidence for impaired attention to task set

Lisa Goelz[1], Leo Verhagen[2], Maya Cottongim[3], Daniel Corcos[4], Fabian David[5]

[1]University of Illinois at Chicago/Northwestern University, [2]Rush University Medical Center, [3]Northwestern Univserity, [4]Northwestern University, [5]Northwestern Physical Therapy

2-A-3 Sensitivity to visual gain modulation in head-mounted displays depends on fixation

Matthew Moroz[1], Isabelle Garzorz[2], Eelke Folmer[1], Paul MacNeilage[1]

[1]University of Nevada, Reno, [2]Ludwig-Maximilian Unviersity of Munich

2-A-4 Microstimulation in a spiking neural network of the midbrain superior colliculus

John van Opstal[1], Bahadir Kasap[2]

[1]Donders Institute Nijmegen, Radboud University, [2]Radboud University Nijmegen

B – Fundamentals of Motor Control

2-B-5 Motor fatigability in humans is associated with a shift from mesial to lateral premotor-motor interactions and changes in motor cortex inhibition

Marc Bächinger[1], Rea Lehner[1], Felix Thomas[2], Samira Hanimann[1], Corina Ryf[2], Joshua Balsters[3], Nicole Wenderoth[1]

[1]Neural Control of Movement Lab, ETH Zurich, [2]Neural Control of Movement Lab, Department of Health Sciences and Technology, ETH Zürich Switzerland, [3]Royal Holloway University of London

2-B-6 Experience-dependent contributions of striatal dopamine to dexterous limb movements

Alexandra Bova[1], Amy Hurst[1], Kai Myran[1], Maya Hammoud[1], Daniel Leventhal[1]

[1]University of Michigan

2-B-7 Separate effects of handedness on prediction and control of hand movement

Mathew James[1], Frederic Danion[1]

[1]CNRS & Aix-Marseille University

2-B-8 Multiple motor memories are formed when implicitly controlling different locations on a tool

Keaton Proud[1], James Heald[2], James Ingram[2], Daniel Wolpert[2], Randall Flanagan[1]

[1]Queen's University, [2]University of Cambridge

2-B-9 Robust developmentally determined spatial muscle synergies revealed in rodent complete SCI and preserved throughout rehabilitation.

Simon Giszter[1], Qi Yang[2]

[1]Drexel University, [2]Weill Cornell Medicine

2-B-10 Movement shapes sensory feedback: movement-history-dependent changes in muscle spindle encoding and muscle fiber stiffness

Brian Horslen[1], Kenneth Campbell[2], Kyle Blum[3], Timothy Cope[4], Paul Nardelli[4], Lena Ting[3]

[1]Emory University, [2]University of Kentucky, [3]Georgia Tech & Emory University, [4]Georgia Institute of Technology

2-B-11 Instruction impedes learning of a new controller

Sarah Hutter[1], Samuel McDougle[1], Jordan Taylor[1]

[1]Princeton University

2-B-12 Successfully stopping a movement has global motor effects as evident in a pause of tonic EMG of an irrelevant effector

Sumitash Jana[1], Adam Aron[1]

[1]University of California San Diego

2-B-13 Stimulus-locked activity in human upper limb muscles and fast online reach adjustments are preferentially evoked by low spatial frequency targets

Philipp Kreyenmeier[1], Rebecca Kozak[1], Chao Gu[1], Kevin Johnston[1], Brian Corneil[1]

[1]Western University

2-B-14 Reward decreases motor fatigability by increasing neural activity within the motor network

Rea Lehner[1], Marc Bächinger[1], Samira Hanimann[1], Céline Ghidoni[1], Joshua Balsters[2], Nicole Wenderoth[1]

[1]Neural Control of Movement Lab, ETH Zurich, [2]Royal Holloway University of London

2-B-15 A computational model of afferented muscles reproduces cardinal features of force variability

Akira Nagamori[1], Christopher Laine[1], Francisco Valero-Cuevas[1]

[1]University of Southern California

2-B-16 Two novel electrode systems for ensemble and single-unit recordings from small muscles.

Andrea Pack[1], Michiel Vellema[2], Stephen Yan[3], Ozan Berberoglu[2], Sushma Sri Pamulapati[3], Matteo Pasquali[3], Coen P.H. Elemans[2], Samuel Sober[1]

[1]Emory University, [2]University of Southern Denmark, [3]Rice University

2-B-17 How self-initiated memorized movements become automatic: A replication and validation study of Wu, Kansaku and Hallett (2004) using functional near-infrared spectroscopy (fNIRS)

Nadia Polskaia[1], Sarah Fraser[1], Gabrielle St-Amant[1], Yves Lajoie[1]

[1]University of Ottawa

2-B-18 Investigating the role of beta oscillations for motor inhibition using brain computer interface

Kathy Ruddy[1], Jemima Schmidt[2], Laura Rueda-Delgado[1], Robert Whelan[1]

[1]Trinity College Dublin, [2]ETH Zürich

2-B-19 The relationship between somatosensory working memory and human motor learning

Ananda Sidarta[1], Katrine Bergeron[1], Floris van Vugt[1], David Ostry[1]

[1]McGill University

2-B-20 Spinal stretch reflexes exploit musculoskeletal redundancy to support postural hand control

Jeff Weiler[1], Paul Gribble[1], Andrew Pruszynski[1]

[1]University of Western Ontario

C – Posture and Gait

2-C-22 Age-related loss of early grasp affordance when viewing a safety handle

David Bolton[1], Douglas McDannald[2], Mahmoud Mansour[1], Garrett Rydalch[1]

[1]Utah State University, [2]Kinesiology & Health Science

2-C-23 Investigating the redesign of a passive cane via a mathematical model of cane assisted upright balance

James Chagdes[1], Amit Shukla[1]

[1]Miami University

2-C-24 Anticipation of split-belt treadmill perturbations drives adaptation of muscle activity in preparation of heel strike

Daniel Gregory[1], Julia Choi[1]

[1]University of Massachusetts

2-C-25 Cerebellar and Parietal Cortex activation predicts walking pattern characteristics during continuous gait adjustments to the split-belt treadmill: An [18F]-FDG PET Study.

Dorelle Hinton[1], Alexander Thiel[1], Laurent Bouyer[2], Caroline Paquette[1]

[1]McGill University, [2]Université Laval

2-C-26 Auditory inputs contribute to balance control in healthy young and older adults: a simulated hearing loss experiment.

Victoria Kowalewski[1], Linda Thibodeau[2], Rita Patterson[1], Nicoleta Bugnariu[1]

[1]University of North Texas Health Science Center, [2]University of Texas at Dallas - Callier Center for Communication Disorders

2-C-27 Gaze and the control of foot placement when walking in natural terrain

Jonathan Matthis[1], Mary Hayhoe[1]

[1]University of Texas at Austin

2-C-28 The effects of different levels of midsole cushioning in footwear on mobility performance of females living with multiple sclerosis

Andrew Monaghan[1], Sutton Richmond[1], Brett Fling[1]

[1]Colorado State University

2-C-29 Dissociation of muscle and cortical response scaling to balance perturbation acceleration

Aiden Payne[1], Greg Hajcak[2], Lena Ting[3]

[1]Georgia Tech & Emory, [2]Florida State University, [3]Emory University & Georgia Tech

2-C-30 Leveling the playing field: evaluation of a portable instrument for quantifying balance performance

Sutton Richmond[1], Kevin Dames[2], Brett Fling[1]

[1]Colorado State University, [2]State University of New York Cortland

2-C-31 Combined dimensionality reduction and regression to identify correlates of step length asymmetry post-stroke

Natalia Sanchez[1], James Finley[1]

[1]University of Southern California

2-C-32 Associations between motor cortex inhibition and gait variability in young and older adults

Clayton Swanson[1], Brett Fling[1]

[1]Colorado State University

2-C-33 Dynamic balance control during obstacle negotiation in individuals with post stroke hemiparesis

Arian Vistamehr[1], Chitralakshmi Balasubramanian[2], David Clark[3], Christy Conroy[1], Richard Neptune[4], Emily Fox[5]

[1]Brooks Rehabilitation, [2]University of North Florida, Jacksonville, [3]Malcom Randall VA Medical Center, [4]The University of Texas at Austin, [5]University of Florida

2-C-34 Control of intersegmental dynamics during perturbation of accurate stepping during locomotion

Humza Zubair[1], Erik Stout[1], Irina Beloozerova[1], Natalia Dounskaia[2]

[1]Barrow Neurological Institute, [2]Arizona State University

D – Integrative Control of Movement

2-D-35 Functional brain activity during motor control and pain processing in chronic jaw-pain

Arnab Roy[1], Wei-en Wang[1], Rachel Judy[1], Margarete Ribeiro-Dasilva[1], Roger Fillingim[1], Stephen Coombes[1]

[1]University of Florida

2-D-36 The influence of kinesthetic motor imagery on goal-dependent modulation of the long-latency stretch response

Christopher Forgaard[1], Ian Franks[1], Dana Maslovat[1], Romeo Chua[1]

[1]University of British Columbia

2-D-37 Contributions of action selection and execution to spatiotemporal interference in a bimanual rhythmic-discrete task

Nikita Kuznetsov[1]

[1]Louisiana State University

2-D-38 Probing sensory signals in motor cortex using a virtual balancing task

Emily Oby[1], Kristin Quick[1], Jessica Mischel[1], Conway Hsieh[1], Patrick Loughlin[1], Aaron Batista[1]

[1]University of Pittsburgh

2-D-39 Reach velocities index word learning in virtual reality

Timothy Shea[1], Chelsea Gordon[1], Ramesh Balasubramaniam[1], David Noelle[1]

[1]University of California, Merced

2-D-40 Change in temporal aspects of movement affect slips of the pen

Chiharu Yamada[1], Yoshihiro Itaguchi[2], Kazuyoshi Fukuzawa[1]

[1]Waseda University, [2]Keio University

E – Disorders of Motor Control

2-E-41 Deep brain stimulation in essential tremor: tremor and dysmetria in the upper and lower limb

Agostina Casamento-Moran[1], Stefan Delmas[1], Basma Yacoubi[1], Michael Okun[1], Aparna Shukla[1], David Vaillancourt[1], Evangelos Christou[1]

[1]University of Florida

2-E-42 Deep brain stimulation in a patient with dystonia modulates spatiotemporal control within hands, but not between hands: a case study

Florian Kagerer[1], Alexander Brunfeldt[1], Phillip Desrochers[1]

[1]Michigan State University

2-E-43 Modular muscle stimulation improves neuromuscular control in post-stroke subjects

Si Li[1], Chuanxin Niu[1], Yong Bao[1], Qing Xie[1], Ning Lan[1]

[1]Shanghai Jiao Tong University

2-E-44 Abnormal antagonist activation during reactive balance is associated with Parkinson's disease and age

Kimberly Lang[1], J. Lucas McKay[2], Madeleine Hackney[3], Lena Ting[2]

[1]Emory University, [2]Emory University and Georgia Tech, [3]Emory Sch. of Med.; Atlanta VA Med. Ctr.

2-E-45 Motor strength or motor control: What matters in chronic stroke?

Prakruti Patel[1], Evangelos Christou[2], Neha Lodha[1]

[1]Colorado State University, [2]University of Florida

2-E-46 Cortical dynamics within and between parietal and motor cortex in essential tremor

Arnab Roy[1], Stephen Coombes[1], Jae Chung[1], Derek Archer[1], Michael Okun[1], Christopher Hess[1], Aparna Shukla[1], David Vaillancourt[1]

[1]University of Florida

2-E-47 Oculomotor movements affect reaching movements in stroke survivors

Tarkeshwar Singh[1], Christopher Perry[2], Troy Herter[2]

[1]University of Georgia, [2]University of South Carolina

2-E-48 StartReact reveals differential reticulospinal control of muscle activation and inhibition during gait initiation in patients with corticospinal degeneration

Vivian Weerdesteyn[1], Bas van Lith[1], Milou Coppens[1], Jorik Nonnekes[1], Alexander Geurts[1]

[1]Radboud University Medical Centre

F – Adaptation & Plasticity in Motor Control

2-F-49 Uncontrolled manifold analysis reveals structure of variability in lip-jaw kinematics during speech production

Satyajit Ambike[1], Jessica Huber[1]

[1]Purdue University

2-F-50 Neural and behavioral sensorimotor adaptation changes in astronauts during spaceflight

Lauren Banker[1], Katherine Bennett[1], Vincent Koppelmans[2], Roy Riascos-Castaneda[3], Nichole Gadd[4], Igor Kofman[4], Yiri De Dios[4], Jacob Bloomberg[5], Ajitkumar Mulavara[4], Rachael Seidler[1]

[1]University of Florida, [2]University of Utah, [3]University of Texas Health Science Center at Houston, [4]KBRwyle Science, Technology and Engineering, [5]NASA Johnson Space Center

2-F-51 Age-related differences in brain activity and changes in deactivation during visuomotor skill learning

Kelly Berghuis[1], Sabrina Fagioli[2], Natasha Maurits[1], Inge Zijdewind[1], Jan-Bernard Marsman[1], Tibor Hortobágyi[1] Giacomo Koch[2], Marco Bozzali[2]

[1]University Medical Center Groningen, [2]IRCCS Fondazione Santa Lucia

2-F-52 Motor cortex changes associated with multisensory perceptual learning

Hannah Block[1], Jasmine Mirdamadi[1]

[1]Indiana University Bloomington

2-F-53 Does prior stance slip-perturbation training augment or mitigate the recovery response to a novel stance trip-perturbation in chronic stroke survivors?

Shamali Dusane[1], Tanvi Bhatt[1]

[1]University of Illinois at Chicago

2-F-54 Eye movements represent explicit learning in hand movement adaptation

Zohar Bromberg[1], Opher Donchin[1], Shlomi Haar[2]

[1]Ben-Gurion University of the Negev, [2]Imperial College London

2-F-55 The fast and slow adaptive processes are malleable based on prior experience

Susan Coltman[1], Joshua Cashaback[2], Paul Gribble[3]

[1]Western University, [2]University of Calgary, [3]University of Western Ontario

2-F-58 Muscle activation during index finger tapping at preset and freely chosen rates

Ernst Hansen[1], Anders Emanuelsen[1], Pascal Madeleine[1], Michael Voigt[1]

[1]Aalborg University

2-F-59 Multiple measurements of aftereffects in a visuomotor adaptation task

Yoshihiro Itaguchi[1], Chiharu Yamada[2], Kazuyoshi Fukuzawa[2]

[1]Keio University, [2]Waseda University

2-F-60 Downregulation of primary sensorimotor missing hand cortex activity is a correlate rather than a driver of phantom limb pain relief

Sanne Kikkert[1], Melvin Mezue[1], Jacinta O'Shea[1], David Henderson-Slater[2], Heidi Johansen-Berg[1], Irene Tracey[1], Tamar Makin[3]

[1]University of Oxford, [2]Nuffield Orthopaedic Centre, [3]University College London

2-F-61 Motor adaptation to novel field dynamics is not associated with proprioceptive acuity in older or younger adults

Nick Kitchen[1], Chris Miall[2]

[1]University of Washington, [2]University of Birmingham

2-F-62 Role of somatosensory cortex in consolidation of motor learning

Neeraj Kumar[1], David Ostry[1]

[1]McGill University

2-F-63 Motor exploration in children and adults when learning a novel motor task

Priya Patel[1], Mei-Hua Lee[1]

[1]Michigan State University

2-F-64 Explicit learning during visuomotor adaptation constitutes of two distinct components: explicit reportable knowledge and explicit control

Jana Maresch[1], Opher Donchin[1]

[1]Ben Gurion University of the Negev

2-F-65 Temporally labile motor adaption is implicit rather than explicit in nature

J. Ryan Morehead[1], Maurice Smith[1]

[1]Harvard University

2-F-66 Distinct neural signatures of reward and sensory prediction error in motor learning

Dimitrios Palidis[1], Joshua Cashaback[1], Paul Gribble[1]

[1]University of Western Ontario

2-F-67 Neural adaptation in response to change in the musculo-skeletal system: A new primate model.

Roland Philipp[1], Tomomichi Oya[1], Kazukiko Seki[1]

[1]National Institute of Neuroscience, National Center of Neurology and Psychiatry

2-F-68 Not all solutions are created equal: Stability influences the exploitation of redundancy

Federica Danese[1], Maura Casadio[1], Rajiv Ranganathan[2]

[1]University of Genoa, [2]Michigan State University

2-F-69 Force field generalization and the internal representation of motor learning

Alireza Rezazadeh[1], Max Berniker[1]

[1]University of Illinois at Chicago

2-F-70 Short-term memory maintenance by motor memory retrieval

Akikazu Sasaki[1], Daichi Nozaki[1]

[1]University of Tokyo

2-F-71 Aim-based generalization shapes local dual adaptation to opposing cursor rotations

Raphael Schween[1], Jordan Taylor[1], Mathias Hegele[1]

[1]Justus-Liebig-University, Giessen, Germany

2-F-72 Motor imagery of different future movements can engage distinct motor memories

Hannah Sheahan[1], James Ingram[2], Goda Zalalyte[2], Daniel Wolpert[2]

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

2-F-73 Motor practice under variable cortical activities fosters the stability of motor memories

Mitsuaki Takemi[1], Toyo Ogasawara[1], Daichi Nozaki[1]

[1]The University of Tokyo

2-F-74 Role of the Corpus Callosum in mediating interlimb transfer of motor skills: Insights from neurological patients.

Penelope Tilsley[1], Patricia Romaiguère[2], Eve Tramoni[3], Olivier Felician[4], Fabrice Sarlegna[2]

[1]Aix-Marseille University, [2]CNRS, [3]APHM, [4]Aix-Marseille University and APHM

2-F-75 Comparing visuomotor adaptation and mirror-reversal learning using system identification techniques

Christopher Yang[1], Noah Cowan[1], Adrian Haith[2]

[1]Johns Hopkins School of Medicine, [2]Johns Hopkins University

G – Theoretical & Computational Motor Control

2-G-76 A history-dependent model of muscle spindle sensory encoding for sensorimotor control research

Kyle Blum[1], Kenneth Campbell[2], Paul Nardelli[3], Timothy Cope[3], Lena Ting[1]

[1]Georgia Tech & Emory University, [2]University of Kentucky, [3]Georgia Institute of Technology

2-G-77 Generalization of the dynamical systems modeling approach to capture interactions between premotor and primary motor cortex and their influences on kinematic features.

Raina Daleo[1], Adam Rouse[2], Marc Schieber[2], Sri Sarma[1]

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

2-G-78 Joint control during arm movements performed during activities of daily living

Natalia Dounskaia[1], Dirk Marshall[1], Dattaraj Sansgiri[1], Joshua Sarbolandi[1], Meghan Vidt[2]

[1]Arizona State University, [2]Pennsylvania State University

2-G-79 Learning to move in a switching environment: a jump Markov model of motor adaptation

James Heald[1], James Ingram[1], Randall Flanagan[2], Daniel Wolpert[1]

[1]University of Cambridge, [2]Queen's University

2-G-80 Cortical posture memories minimize work

Lijia Liu[1], Dana Ballard[1]

[1]University of Texas at Austin

2-G-81 Markerless tracking of user-defined anatomical features with deep learning

Mackenzie Mathis[1], Alexander Mathis[2], Pranav Mamidanna[3], Taiga Abe[3], Ventatesh Murthy[4], Matthias Bethge[5]

[1]Harvard University - University of Tübingen, [2]University of Tübingen - Harvard University, [3]University of Tübingen, [4]Harvard University, [5]University of Tübingen -- MPI Tübingen

2-G-82 Parametric versus discrete working memory representations in sensorimotor learning

Samuel McDougle[1], Jordan Taylor[1]

[1]Princeton University

2-G-83 Interactions of balance control and locomotion in cats walking on a split-belt treadmill

Yaroslav Molkov[1], Elizaveta Latash[1], Hangue Park[2], Alexander Klishko[2], Boris Prilutsky[2]

[1]Georgia State University, [2]Georgia Institute of Technology

2019 Annual Meeting

April 21–26, 2019

Society for the
Neural Control of Movement
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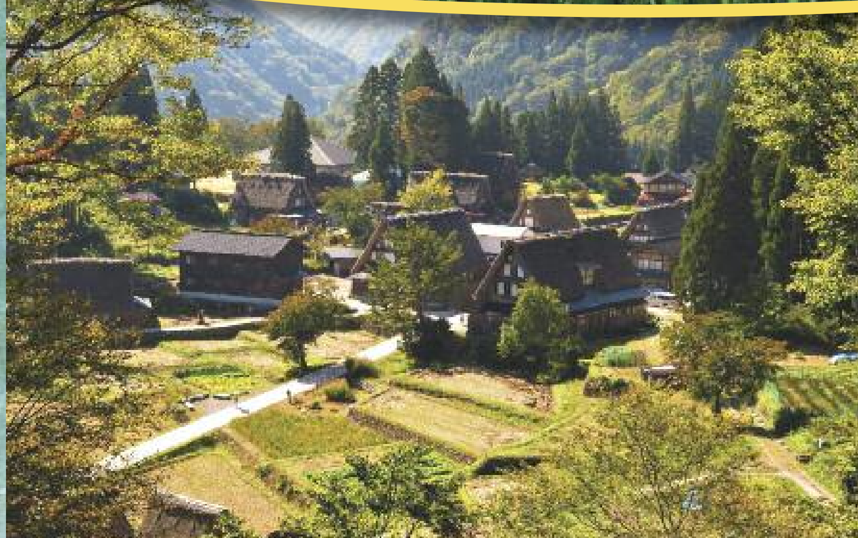

We are pleased to announce that the **NCM 29th Annual Meeting** will take place **April 21–26, 2019 at the Toyama International Conference Center,** in Toyama, Japan

Toyama, Japan, an area full of nature with the Northern Alps, including the 3,000 meter Tateyama Mountain Range, and the bountiful Toyama Bay.

Toyama Prefecture is surrounded by nature and offers a wide variety of sights and local cuisine to enjoy.

There is an abundance of must-see sights, such as the world-famous Tateyama Kurobe Alpine Route and the remote mountain village of *gassho*-style houses in the World Heritage Site of Gokayama, as well as Zuiryu-ji and other historic temples and modern museums.

Toyama is sure to be a meeting not to be missed!

Some key dates

Abstract Submission Opens: October 29, 2018

Oral and Team Submissions Close: November 29, 2018

Poster Submissions Close: February 25, 2019

Early Bird Registration Deadline: March 11, 2019

2-G-84 Hypermetria after exposure to visuomotor delay in a virtual game is caused by unaware adaptation of movement planning

Erez Sulimani[1], Guy Avraham[1], Ferdinando Mussa-Ivaldi[2], Ilana Nisky[1]

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

2-G-85 Action selection under conflict: replacement versus suppression of competing response options

Jing Xu[1], Laxaviera Elphage[1], Adrian Haith[1]

[1]Johns Hopkins University

2-G-86 Objects without boundaries: generalization between visual statistics and physical affordances

Goda Zalalyte[1], Alexandros Pantelides[1], James Ingram[1], Gábor Lengyel[2], József Fiser[2], Máté Lengyel[1], Daniel Wolpert[1]

[1]University of Cambridge, [2]Central European University

Poster Cluster

2-G-87 Learning expands the planning horizon in finger sequence tasks

Neda Kordjazi[1], Jörn Diedrichsen[1]

[1]University of Western Ontario

2-F-88 What are the fMRI signatures for plasticity during motor sequence learning?

Eva Berlot[1], Nicola Popp[1], Jörn Diedrichsen[1]

[1]University of Western Ontario

2-F-89 Selection, preparation, execution: breaking down elements of skill learning

Giacomo Ariani[1], Jörn Diedrichsen[2]

[1]The Brain and Mind Institute, [2]University of Western Ontario

Notes

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ANT Neuro

www.ant-neuro.com

ANT Neuro offers products tailored to the needs of movement scientists and other clinical neuroscientists. ANT's eego line of EEG products was developed from the ground up to allow collection of high density EEG and EMG data during movement without compromising data quality. ANT also offers the visor2 TMS navigation and functional mapping system which enables efficient mapping of motor cortical areas, language areas, and image guided navigation of TMS coils. Using ANT Neuro products, functional brain information can be fused with anatomical scans to gain insight into the working mechanisms of cognition and a variety of brain disorders.

Visit us at **Exhibit Booth 6**

BKIN Technologies Ltd

www.bkintechnologies.com

BKIN is the leading developer of robotic technologies for understanding brain function and dysfunction. KINARM Labs are flexible robotic platforms that address sensory and motor control researchers' needs for measurement and action of the upper limb. Users span the basic and clinical research continuum. We continuously strive to incorporate requests to meet your research needs. The new KINARM Exoskeleton, providing 3X improved stiffness over the KINARM Classic and full access to the head to enable use of TMS, tDCS, etc., is now in full production.

Email: info@bkintechnologies.com @BKINTech

Blackrock Microsystems

www.blackrockmicro.com

Blackrock Microsystems is a privately held company that provides enabling tools for the neuroscience, neural engineering and neuroprosthetics research and clinical community worldwide. The Blackrock team backs up your project from start to finish so you can publish faster. All our solutions provide high-quality, reliable data because they are precisely tailored to your project needs and fully integrated. Blackrock systems are known for their user-friendliness and intuitive, plug-and-play experience. Such ease of use and reliability is possible because we offer the largest portfolio of FDA and CE approved products, which are by definition more documented, proven, reliable and safe.

Email: mvalenzuela@blackrockmicro.com

www.twitter.com/BlackrockMicro

www.facebook.com/BlackrockMicro

Visit us at **Exhibit Booth 3**

Journal of Neurophysiology

www.physiology.org/journal/jn

The Journal of Neurophysiology publishes original articles on the function of the nervous system. All levels of function are included, from the membrane and cell to systems and behavior. Experimental approaches include molecular neurobiology, cell culture and slice preparations, membrane physiology, developmental neurobiology, functional neuroanatomy, neurochemistry, neuropharmacology, systems electrophysiology, imaging and mapping techniques, and behavioral analysis. Experimental preparations may be invertebrate or vertebrate species, including humans. Theoretical studies are acceptable if they are tied closely to the interpretation of experimental data and elucidate principles of broad interest.

Email: jnpeditor@the-aps.org

@JNeurophysiol

www.facebook.com/JournalofNeurophysiology

Visit us at **Exhibit Booth 1**

Micro-Leads, Inc

www.micro-leads.com

Micro-Leads delivers multi-channel wireless stimulator and recording implantable devices and headstages to enable closed-loop and untethered peripheral nerve and cortical sensory-motor experimental paradigms. Self-closing precision nerve cuffs rapidly attach to 100 μm to 5 mm peripheral nerves, streamlining the surgical preparations and providing chronic stability. Ultra-soft, fusion-electrodes conform to the surface of the spinal cord, brain (μEcOG, EcOG), and nerve plexuses and can be rapidly-customized in under 4 weeks.

Email: info@micro-leads.com

Visit us at **Exhibit Booth 7**

NDI

www.ndigital.com

NDI is a global-leading innovator and manufacturer of advanced 3D measurement and motion tracking systems. Our Optotrak Certus® optical tracker is well known for its micron-level measurement accuracy and reliability, capturing the most subtle of movements with minimal lag and noise. Fast update rates, system pre-calibration, and automatic marker identification put the focus on quick, accurate data capture. For over 35 years, NDI solutions have been trusted by thousands of researchers – and cited in thousands of papers – around the world.

Email: msci@ndigital.com

@ndimeasurement

Plexon, Inc.

www.plexon.com

Plexon is a pioneer and leading innovator of custom, high performance data acquisition, behavior and analysis solutions specifically designed for scientific research. We collaborate with and supply thousands of customers including the most prestigious neuroscience laboratories around the globe driving new frontiers in areas including basic science, brain-machine interfaces (BMI), neurodegenerative diseases, addictive behaviors and neuroprosthetics. Plexon offers integrated solutions for in vivo neurophysiology, optogenetics and behavioral research -- backed by its industry-leading commitment to quality and customer support.

Visit us at **Exhibit Booth 2**

Ripple

www.rippleneuro.com

Ripple creates neural interface and medical devices to advance research and improve the lives of under-served patient populations through thoughtful application of technology and design.

Email: sales@rppl.com

Visit us at **Exhibit Booth 5**

Society for Neuroscience

www.sfn.org

The Society for Neuroscience is the world's largest organization of scientists and physicians devoted to understanding the brain and nervous system. The nonprofit organization, founded in 1969, now has nearly 37,000 members in more than 90 countries worldwide.

Email: kfoster@sfn.org

Visit us at **Exhibit Booth 8**

Sutter Instrument

www.sutter.com

Quality. Precision. Reliability. For over 40 years, Sutter Instrument has set the highest standards for performance and innovation. New products include the Lambda 421 Optical Beam Combiner that combines separate light sources with different spectra into a single common output beam, the TRIO 3-axis micromanipulator, the BOB, an open-design upright microscope ideal for slice electrophysiology, wide field imaging, 2-photon retinal imaging and photostimulation, and the Double IPA (Integrated Patch Amplifier), an all-in-one low-noise dual patch clamp amplifier, onboard D/A conversion and data acquisition system, and powerful SutterPatch software built on the foundations of Igor 7.

Email: info@sutter.com

Tucker-Davis Technologies

www.tdt.com

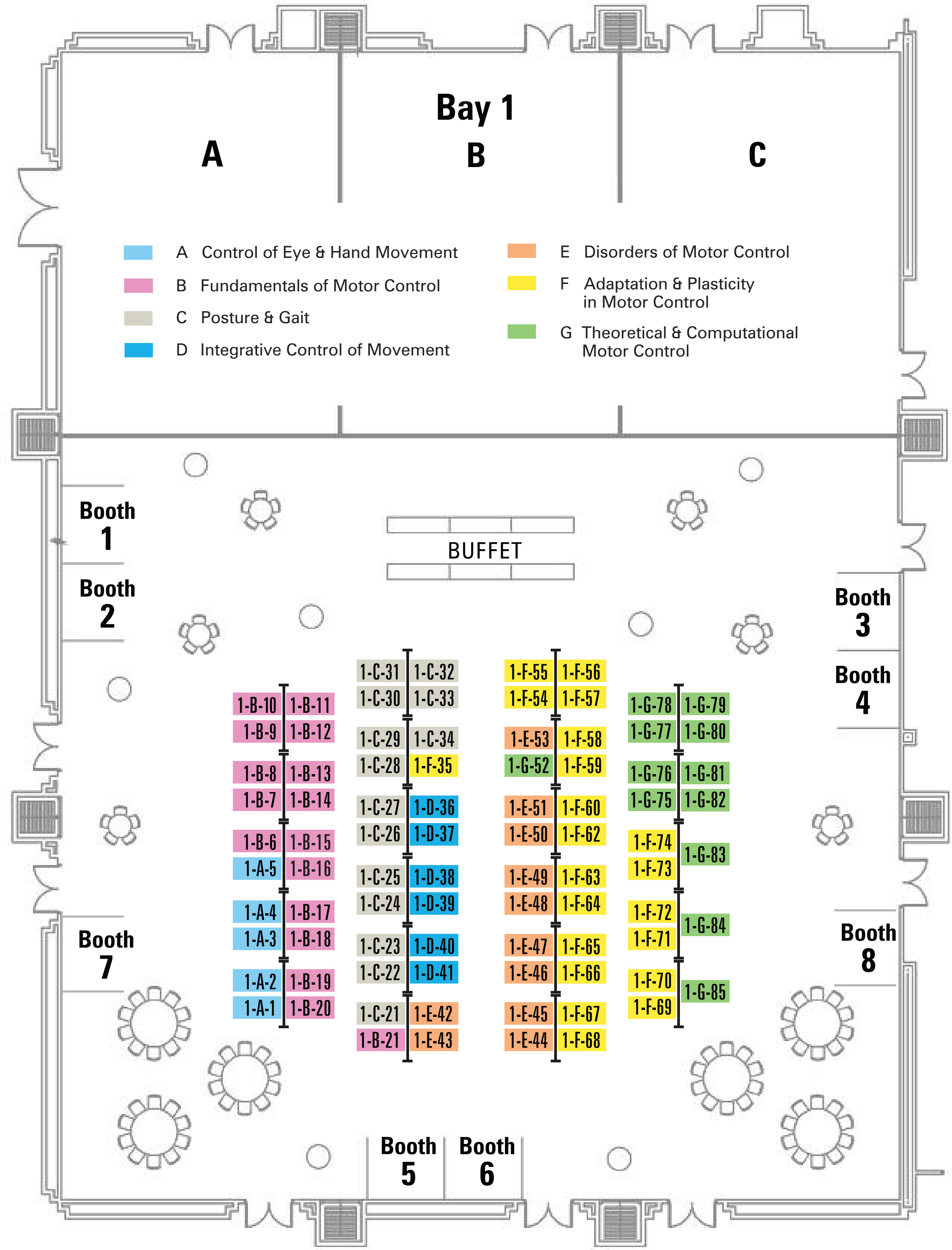
Tucker-Davis Technologies (TDT) provides products for basic and applied research in the neurophysiology, hearing, and speech sciences as well as for general data acquisition applications. We offer a complete line of modular DSP-based data acquisition and stimulus generation systems. At TDT, we work closely to achieve our common goal: to supply you with the highest quality, most up-to-date technology available at an affordable price. We believe we can best meet this goal when all areas of our business work together in a cooperative and collaborative environment.

Email: akelley@tdt.com

Visit us at **Exhibit Booth 4**

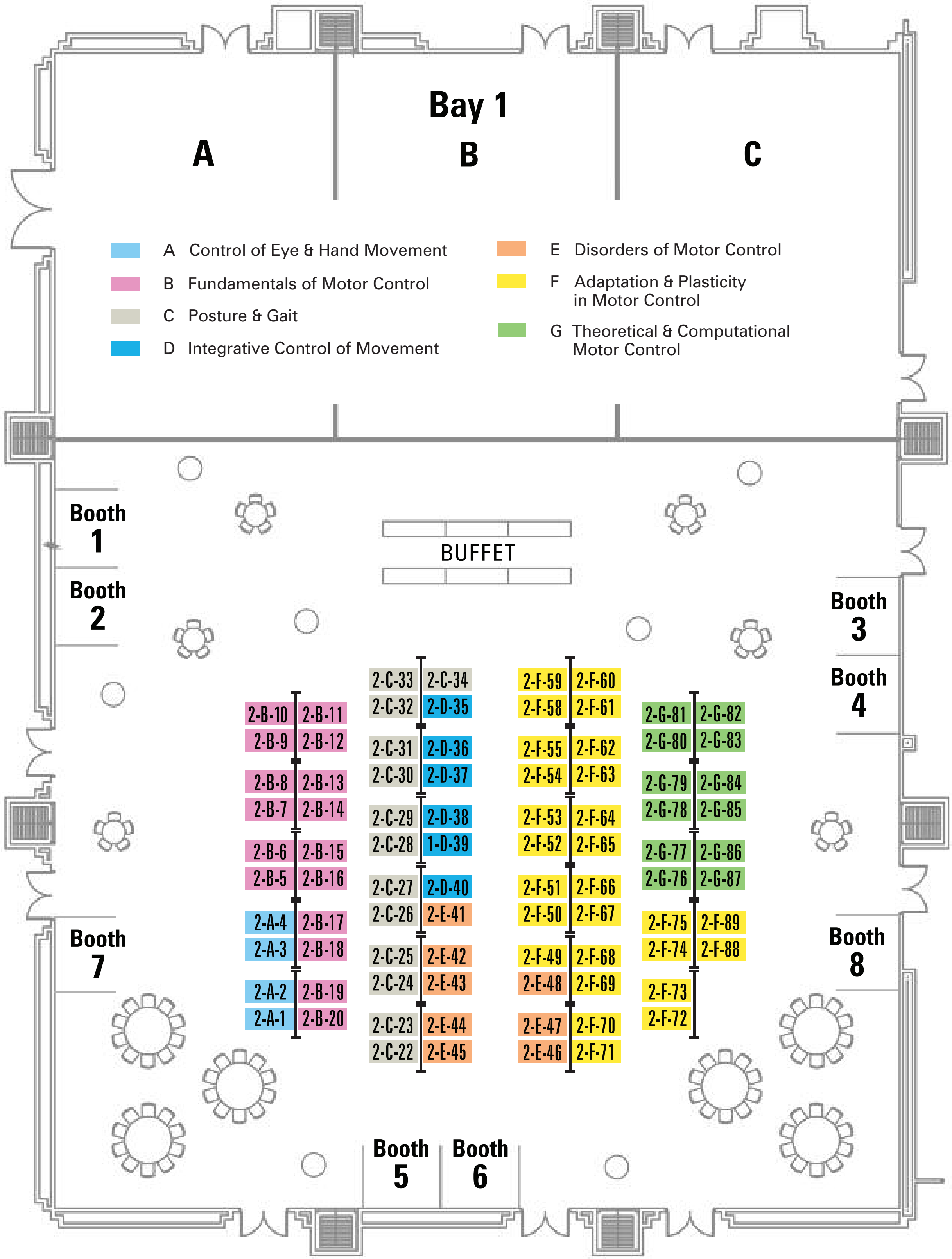
Poster Session 1 Floor Plan • Tewa Room

Tuesday May 1 & Wednesday May 2   8:00 – 17:00



Poster Session 2 Floor Plan • Tewa Room

Thursday May 3 & Friday May 4 8:00 – 14:45



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