Society for the
Neural Control of Movement

NCM

NCM 23RD Annual Meeting

Satellite Meeting
April 15 – 16, 2013

23rd Annual Meeting
April 16 – 20, 2013

El San Juan Hotel & Casino
A WALDORF ASTORIA HOTEL

San Juan **Puerto Rico**

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

2013 At-A-Glance Satellite and Annual Conference Schedule

El San Juan Hotel & Casino, Puerto Rico

NCM

Society for the
Neural Control of Movement

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

Monday 15-Apr
- Arrivals, Free Time, Excursions
- Satellite Registration (17:00 - 19:00)
- Satellite Drinks Reception (18:00 - 19:00)
- Satellite Registration

Tuesday 16-Apr
- Satellite Registration
- Satellite Meeting Coffee Service
- Satellite Meeting *Session 1* Motor development and behavior (09:45 - 12:00)
- Lunch (12:00 - 13:00)
- Satellite Meeting *Session 2* Cellular and electrophysiologic basis of developmental plasticity (13:00 - 15:00)
- Break
- Satellite Meeting *Session 3* Motor disorders during development (15:15 - 17:30)
- Conference Registration (17:00 - 19:00)
- Opening Dinner (19:00 - 21:00)
- Registration /Information Desk Open
- Registration (17:00 - 19:00)

Wednesday 17-Apr
- *Session 1* Panel I Diedrichsen (08:00 - 10:15)
- Break (10:15 - 10:45)
- *Session 2* Panel II Romanski (10:45 - 13:00)
- Session 3 Poster 1a Lunch (13:00 - 15:00)
- *Session 4* Short Perspective I (15:00 - 16:00)
- *Session 5* Individual Presentations I (16:00 - 17:20)
- Free Time and/or Excursions: Bio Bay Kayak (18:15 - Depart from HQ Hotel Lobby)
- Exhibits on Display
- Posters on Display (Session 1)
- Registration / Information Desk Open

Thursday 18-Apr
- *Session 6* Individual Presentations II (08:00 - 10:15)
- Break (10:15 - 10:45)
- *Session 7* Panel III Gallivan (10:45 - 13:00)
- *Session 8* Poster 1b Lunch (13:00 - 15:00)
- *Session 9* Perspective Panel I Giszter P (15:00 - 16:30)
- Members Business Meeting (16:30 - 17:30)
- Free Time and/or Excursions: Bio Bay Kayak (18:15 - Depart from HQ Hotel Lobby)
- Exhibits on Display
- Posters on Display (Session 1)
- Registration / Information Desk Open

Friday 19-Apr
- *Session 10* Individual Presentations III (08:00 - 10:15)
- Break (10:15 - 10:45)
- *Session 11* Panel IV Omrani (10:45 - 13:00)
- Session 12 Poster 2a Lunch (13:00 - 15:00)
- Free Time and/or Excursions: Bio Bay Kayak (16:00 - Depart from HQ Hotel Lobby)
- Exhibits on Display
- Posters on Display (Session 2)
- Registration / Information Desk Open

Saturday 20-Apr
- *Session 13* Panel V Oostwoud Wijdenes (80:00 - 10:15)
- Break (10:15 - 10:45)
- *Session 14* Individual Presentations IV (10:45 - 13:00)
- *Session 15* Poster 2b Lunch (13:00 - 15:00)
- *Session 16* *Keynote Address* Tom Jessell (15:00 - 17:00)
- Closing Drinks Reception (17:00 - 18:00)
- Free Time and/or Excursions
- Exhibits on Display
- Posters on Display (Session 2)
- Registration / Information Desk Open

Sunday 21-Apr
- Breakfast and Departures

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, behavioural, computational and theoretical neurobiologists, and clinician-investigators interested in disorders of motor function.

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

The inaugural NCM Conference took place in April 1991 on Marcos Island, Florida, with roughly 140 attendees. The success of the initial years promoted longevity and expansion of NCM and its conference, both in attendance (now over 250, with membership over 400) and the breadth of scientific content. Sessions cover all levels of inquiry, from perception to genetic expression, and from whole organism to intracellular function, while also including computational and theoretical approaches. This highly regarded conference continues to meet in desirable, family-friendly locations, typically in April every year.

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Welcome

To the Society for the Neural Control of Movement 23rd Annual Meeting

Gary Paige, President

Welcome to our 23rd Annual Conference in San Juan, Puerto Rico. At this time it is fitting to provide some comments about NCM, the meeting, and its venue. First, the Society remains both healthy and growing. We have over the past decade witnessed a progressively climbing membership and meeting attendance. This growth has been subdued in the last couple of years given economic recession, and yet engagement and attendance has not faltered. The upcoming conference is shaping up to be among our most exciting. NCM continues to attract new and established investigators across our unique blend of disciplines that in turn infuses an unusual range of presentation formats, all matched by a mix of vibrancy, diversity, informality and collegiality. Thanks are due to all within the NCM community.

Second, NCM will continue to succeed only in light of novelty, which ultimately means new members and contributors that stem from young investigators. Roughly a quarter of meeting attendance now constitutes students. Further, our scholarship program has grown substantially, thanks to the remarkable efforts of Terry Sanger, our Development Officer. Awards continue to be scattered across North America and abroad alike.

Third, we continue to hone our annual meetings through experiments. These include identifying new meeting sites in our future, as you will learn at the meeting. Meanwhile, Puerto Rico has the potential to become the "new Florida" for reasons expressed at our earlier meeting here 2 years ago. The costs, ecology, and conveniences (scientific and social) all add to substantial benefits for us. Our next experiment will bring us to Europe once again (see page 4 for more information). For the following year I am seeking a novel surprise in the US, and look forward to presenting more at the upcoming business meeting in San Juan – please attend.

Fourth, experiments in meeting structure continue. Doug Munoz, our VP and Program Chair has once again organized a magnificent program for San Juan that continues to morph according to the context of our yearly proposals and individual offerings. We continue our new tradition of holding a grazing lunch during afternoon poster sessions (two days for each of two sets of posters) while also providing time to visit our sponsors' exhibits. This also means that the meeting will engage attendees through the day, ending earlier on some days to allow time with family, friends and colleagues into the evening. I and the Board (identifiable by our badges) solicit your feedback on all of the above and the meeting's content.

Fifth, we continue the substantial benefits of our collaboration with De Armond Management Ltd. The guidance and support they are providing for our Society's affairs and for the planning and management of our Conference allow us to enhance the offerings and service to all members. Marischal, Laurie and Breda (new this year) remain available to you throughout the conference to help with any questions or support you need to ensure you have a quality experience during the meeting.

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

Cordially,

Gary Paige, President

NCM Leadership

Doug Munoz

Steve Scott

Terry Sanger

Elected members govern the Society for the Neural Control of Movement. These members comprise the Board of Directors who in turn elect 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:

Officers (Executive Committee)

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

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

Treasurer & Secretary
Steve Scott (treasurer@ncm-society.org)

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

Board Members

Name	**Institution**	**Country**	**Term**
Tim Ebner	University of Minnesota	USA	2010 - 2013
Lee Miller	Northwestern University	USA	2010 - 2013
John Krakauer	Columbia University	USA	2010 - 2013
Kathy Cullen	McGill University	Canada	2010 - 2013
Amy Bastian	Kennedy Krieger Institute	USA	2011 - 2014
Randy Flanagan	Queens University	Canada	2011 - 2014
Paul Cisek	University of Montreal	Canada	2011 - 2014
Jeroen Smeets	VU University Amsterdam	Netherlands	2011 - 2014
Andrea d'Avella	Fondazione Santa Lucia	Italy	2012 - 2015
Chris Miall	University of Birmingham	UK	2012 - 2015
Andrew Pruszynski	Umea University	Sweden	2012 - 2015
Daichi Nozaki	University of Tokyo	Japan	2012 - 2015

Incoming Board Members

The following members will begin their term at the Annual Meeting.

Name	**Institution**	**Country**	**Term**
Lena Ting	Emory University	USA	2013 - 2016
Brian Corneil	University of Western Ontario	Canada	2013 - 2016
John van Opstal	Donders Institute	Netherlands	2013 - 2016
Rachel Seidler	University of Michigan	USA	2013 - 2016

Board Service

Nominations for NCM Board service open in the late fall of 2013. Nominations must come from members in good standing, and only members are invited to stand for election. To learn more about Board service or if you are interested in serving on the NCM Board, please discuss your interest with one of NCM's Board Members or Officers, or send an email to Treasurer@NCM-Society.org.

NCM Administration

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

De Armond Management Ltd.
Breda Hamill
Laurie De Armond
Marischal De Armond

Membership Information

Society for the
Neural Control of Movement
NCM

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

NCM membership includes the following benefits:

- Opportunity to submit proposals and abstracts for sessions at the Annual Conference
- Opportunity to submit proposals for satellite meetings
- Opportunity to register for Annual NCM Conferences at reduced registration rates
- Access to the member resource database and other members' web services
- Professional development and networking
- Ability to post job opportunities
- Access and ability to respond directly to job opportunity postings
- Access to online NCM resources and Annual Meeting proceedings
- Access to scholarships (Grad Students and Post Docs)
- Opportunity to vote in Annual Elections of NCM Board Members
- Opportunity to stand for election 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.

Future Meetings

2014 Annual Meeting and Satellite

We are pleased to announce the 2014 Annual Meeting and Satellite will take place in one of the most vibrant cities in Europe. Please plan to attend the 24th Annual Meeting in Amsterdam, The Netherlands.

The Annual Meeting will take place April 22 – 26, 2014 at the NH Grand Hotel Krasnapolsky, a luxurious 5-star hotel and conference centre, located in the very heart of Amsterdam city overlooking Dam Square and conveniently located 20 minutes from Amsterdam-Schiphol International Airport (AMS). This venue takes pride in its historic building that houses spacious accommodations and a lush courtyard covered with glass. Dam Square is just a few steps away from the property and there are other attractions that are within walking distance, including the Royal Palace. There will also be alternative, lower cost, accommodation options available for students throughout the city with the NH Hotel Group. This is one meeting you will not want to miss. Plan now to attend. Information about the meeting and the hotel (including reservation information) will be available on the NCM website shortly.

2014 Satellite Meeting – April 22, 2014: **Vestibular Processing in Motor Control**

Organized by:

Paul MacNeilage: Ludwig-Maximilians University Munich
Jeroen Smeets: VU University Amsterdam
Pieter Medendorp: Radboud University Nijmegen
John van Opstal: Radboud University Nijmegen

This one-day satellite meeting, preceding the 2014 NCM meeting, will discuss the role of vestibular processing in motor control, focusing on modern approaches of study in this field. There will be three oral sessions and one poster session giving everybody ample opportunity to discuss the newest results. Presenters will represent a strong mix of well-established and new players in this field and will each have 30 minutes to present.

The three oral sessions include:

- a session on probabilistic and predictive mechanisms, discussing how the field went from transfer functions to probabilistic methods;
- a clinical session focusing on vestibular disorders and the development of current therapies, and;
- a session highlighting the integrative aspects of vestibular function in motor control, spatial cognition, and motor learning.,

Satellite Meetings

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

Keynote Speakers

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

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

Tentative 2014 Satellite Meeting Program

April 22, 2014

Start 08:45 **Introduction**

John van Opstal - Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behaviour, Centre for Neuroscience, Dept of Biophysics

09:00-10:30 **Session 1**

Probabilistic methods and predictive mechanisms in vestibular processing

Chair: **Paul MacNeilage** - Ludwig-Maximilians University Munich, Department of Neurology, Center for Sensorimotor Research

Three speakers – to be confirmed

10:30-11:00 **Break**

11:00-13:00 **Session 2**

Vestibular Disorders and Therapies

Chair: **Pieter Medendorp** - Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behaviour, Centre for Cognition, Sensorimotor Lab

Four speakers – to be confirmed

13:00-15:30 **Lunch + Poster Session**

15:30–17:30 **Session 3**

Vestibular Cognition

Chair: **Jeroen Smeets** - VU University Amsterdam, Faculty of Movement Sciences

Four speakers – to be confirmed

NCM History

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**
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, FL	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, FL	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, FL	USA	Sonesta Beach Resort
15th Annual Meeting	April 12 – 17, 2005	Key Biscayne, FL	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, FL	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, FL	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, FL	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, FL	USA	Radisson Suite Beach Resort
5th Annual Meeting	April 18 – 25, 1995	Key West, FL	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, FL	USA	Radisson Suite Beach Resort
2nd Annual Meeting	April 21 – 26, 1992	Marco Island, FL	USA	Radisson Suite Beach Resort
1st Annual Meeting	April 6 – 11, 1991	Marco Island, FL	USA	Radisson Suite Beach Resort

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

General Information

Meeting Venue

El San Juan Hotel & Casino
A Waldorf Astoria Hotel

6063 Isla Verde Avenue
San Juan (Carolina), Puerto Rico

The conference venue is the El San Juan Hotel & Casino. All conference sessions will take place in this location.

Registration

Satellite Meeting

Satellite Meeting registration fees include a complimentary drink during a drop-in gathering on April 15th, access to the full day meeting with refreshment breaks and a buffet lunch.

Annual Conference

Annual Conference registration fees include access to all sessions including panel, perspective, individual, and poster sessions. Registration also includes daily refreshment breaks, grazing lunches, the Opening Dinner and the Closing Drinks Reception.

Additional Tickets

Tickets can be purchased separately for your guests and/or children for the Opening Dinner, Closing Drinks Reception and Grazing Lunches. Breakfast vouchers for the El San Juan breakfast buffet can be purchased separately for all registrants and their guests at a discounted rate. These additional tickets can only be purchased from the staff at NCM's Registration Desk.

Name Badges

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

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

Dress Code

Dress is casual for all NCM meetings and social events.

Registration and Information Desk Hours

The NCM Registration and Information Desk, located in the Ballroom Foyer, will be open during the following times:

Monday, April 15	17:00 – 19:00
Tuesday, April 16	08:00 – 15:00 & 17:00 – 19:00
Wednesday, April 17	08:00 – 15:00
Thursday, April 28	08:00 – 15:00
Friday, April 29	08:00 – 15:00
Saturday, April 30	08:00 – 15:00

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

Poster Information

Set-Up / Removal

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

Session 1 - Ballroom B & C

Set-up: Wednesday, April 17, between 07:00 and 10:00

Remove: Thursday, April 18, between 17:30 and 18:00

Session 2 - Ballroom B & C

Set-up: Friday, April 19, between 07:00 and 10:00

Remove: Saturday, April 20, between 17:00 and 17:30

Information on Poster Authors (Lead), Poster Numbers and Poster Titles begins on page 34. A full Poster Author Index can be found on page 46. For a complete copy of all the poster abstracts, a limited supply of printed abstracts is available for purchase at the Registration Desk. Digital copies can be downloaded from the Member Only section of the NCM Website.

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

Message Board

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

Staff

NCM staff from De Armond Management Ltd can be identified by ribbons on their name badges. Feel free to ask anyone of our staff for assistance. For immediate assistance please visit us at the Registration Desk.

Conference Excursions

A limited number of spaces remain for the Bio-Luminescent Bay kayak trips. If you are interested in joining one of these trips, please inquire at the Registration Desk.

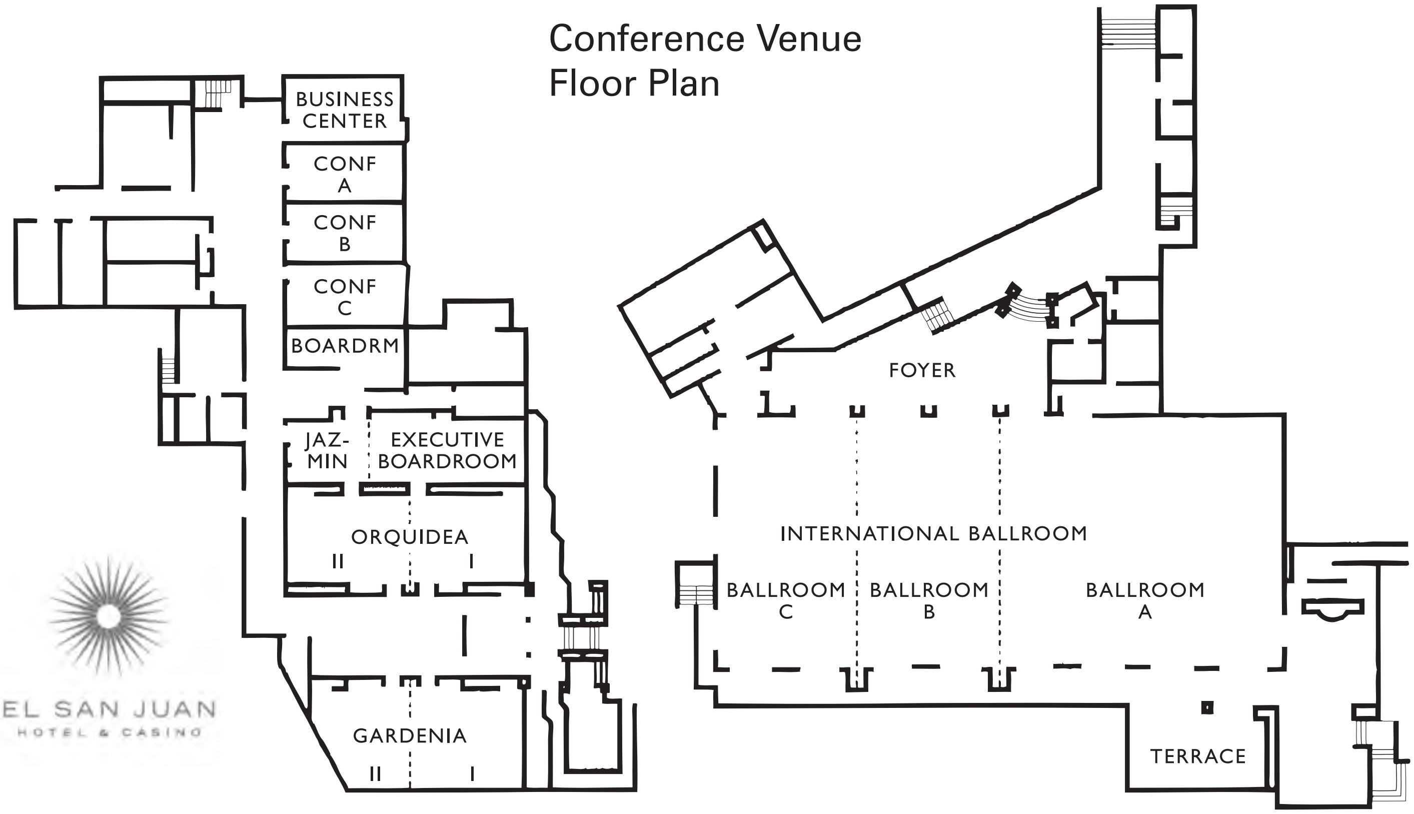
Arrangements have also been made for NCM delegates and guests to reserve places on existing trips and excursions organized by GSI Puerto Rico, the El San Juan Hotel's in-house group travel partner. Visit their travel desk located just inside the exit to the pool and beach area, for more information on the many trips they offer.

Daycare Services

The conference hotel provides a Kids Klub at a cost of $50/day for children ages 3 – 15 years. This program runs from 10:00 am – 4:00 pm daily. Lunch, snacks and drinks are provided. This can be booked through the Pool Concierge, located just outside the exit to the pool and beach area. Advance reservations are encouraged.

If you need access to child care outside of these times, a private babysitting service is available at $20/hour. If you are interested in this service, please visit the Hotel Concierge located next to the Hotel Registration Desk.

Conference Venue Floor Plan



Internet Services

Bedrooms booked through NCM's group room block includes complimentary wireless internet. Depending on signal strength, this service will allow connection throughout the resort's public spaces, meeting pre-function area and the pool area. Connection information is available through the hotel's front desk.

Internet access for the meeting space must be purchased. If you require internet in the meeting space and did not arrange this when you registered, please visit the registration desk.

No Smoking Policy

The El San Juan Hotel is a completely non-smoking facility. Smoking areas are located outside the front entrance to the hotel or along the beach.

Special Meetings & Events

Monday, April 15

18:00 – 19:00	**Satellite Drinks Reception** (Satellite Meeting Registrants Only) The Gold Bar, Hotel Lobby

Tuesday, April 16

7:00 PM – 10:00 PM	**Opening Dinner** (cash bar) Meeting Registrants* – weather dependent) Encanto Bar & Grill *tickets are available for Satellite Meeting Only Registrants at the Registration Desk

Thursday, April 18

16:30 – 17:30	**NCM Business Meeting** Ballroom A

Saturday, April 20

17:00 – 19:00	**Closing Drinks Reception** (one complimentary drink, cash bar) Ballroom Foyer

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Satellite Meeting Detailed Daily Schedule

NCM Satellite Meeting, San Juan, Puerto Rico

April 15 - 16, 2013 All sessions will be held in Ballroom A

Development of Neural Control of Movement

Main Organizer: Sahana N. Kukke, PhD
Co-Organizer: Terence D. Sanger, MD PhD

Early motor development is foundational for the immense diversity of human movement we are familiar with as adults. It is a period of dramatic change behaviorally and physiologically, and is especially vulnerable to injury. The 2013 NCM Satellite Meeting features the work and perspectives of 10 basic and clinical scientists whose research is devoted to the development of neural control of movement. The meeting is organized into three sessions, each with 3-4 presentations and a panel discussion period. In the first session, we will address different aspects of motor development and behavior, including patterns of muscle and corticospinal tract activity in locomotor development, variability during development, and the formation of postural regulation. In the second session, we will explore the potential capacity and flexibility of the developing motor system of vertebrates and underlying cellular mechanisms that drive developmental potential. In the third session, we will focus on the pathophysiology of unilateral cerebral palsy, a common childhood motor disorder, as well as methods and mechanisms of rehabilitation. The goal of this meeting is to present recent work on the topic of early motor development and stimulate discussion to promote further studies.

Monday, April 15

17:00 - 19:00 Satellite Registration, Ballroom Foyer
18:00 – 19:00 Welcome Reception, Gold Bar, El San Juan Hotel

Tuesday, April 16

09:00 - 09:30 Coffee Service
09:30 - 09:45 Introduction of Meeting: Sahana Kukke and Terence Sanger

09:45 – 12:00 **Session 1**

Motor development and behavior

Chairperson: Francesco Lacquaniti, MD, Spec. Neurol

This session will address several different issues of the development of typical and atypical motor development.

1. Francesco Lacquaniti, MD, Spec. Neurol (University of Rome Tor Vergata, Italy):
Evolutionary developmental modules of locomotion

Francesco Lacquaniti will review recent evidence that the addition of new premotor modules underlies the postnatal acquisition and refinement of different motor behaviors in vertebrates. In particular, he will illustrate the development of the patterns of muscle commands and the spatio-temporal maps of motor neuron activation in human locomotion by comparing data from newborns, toddlers, preschoolers, and older children.

2. Jaynie Yang, PhD (University of Alberta, Canada):
Development of locomotor behavior in infants and implications for improving walking after early injury

Jaynie Yang will review data showing that stepping in infants <1 year old exhibits much of the complexity seen in adults, including functionally relevant responses to perturbations. Locomotor development is likely molded by maturation of descending input from the brain. She will present preliminary evidence that intensive activity during a critical period of the corticospinal tract development can mold its maturation in children with perinatal injury to the tract.

3. Christine Assaiante, PhD (CNRS, Marseille, France):
Action and representation of action during childhood and adolescence: a functional approach

Christine Assaiante will argue for the existence of distinct turning points during development of postural regulation, including the period around 6/7 years of age and adolescence. She will show the specific features at those ages of learning processes leading to the selection of postural strategies. Anticipatory development of postural control continues up to surprisingly late periods during childhood and adolescence.

KINARM

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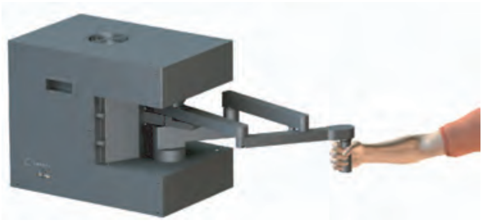

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- Data acquisition hardware: 32 channels of analog input plus 8 DIO
- Interface to neural recording system: 16 channels of analog output plus 24 DIO
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Tuesday, April 16 *Continued*

4. Mijna Hadders-Algra, MD PhD (University Medical Center Groningen, the Netherlands):
Variation and variability: key words in typical human motor development

Mijna Hadders-Algra will review data showing that typical human motor development is characterized by variation and the development of adaptive variability. Atypical motor development is characterized instead by limited variation (a limited size of the repertoire of motor strategies) and a limited ability to vary motor behavior according to the specifics of the situation.

12:00 – 13:00 **Lunch**

13:00 – 15:00

Session 2

Cellular and electrophysiologic basis of developmental plasticity

Chairperson: Nina Bradley, PhD

This session explores the potential capacity and flexibility of the developing motor system of vertebrates and underlying cellular mechanisms that drive developmental potential.

1. Nina Bradley, PhD (University of Southern California, USA):
Adaptive flexibility as evidenced by adjustable timing of locomotor circuit development during embryogenesis

Nina Bradley will explore the potential for adaptive flexibility as evidenced by adjustable timing of locomotor circuit development during embryogenesis in the chick. Is there a cost to pay for being an early or late bloomer? Is the early bloomer denied prenatal practice enjoyed by the late bloomer? Chicks begin to walk hours after hatching, and environmental conditions, such as light exposure, can shorten or lengthen the time to hatch. Some behavioral measures suggest the early bloomer may enjoy small but significant advantages. Recent evidence suggests that the rate of locomotor circuit development positively varies with light exposure during embryogenesis and that the early bird may get the worm because her locomotor circuits matured at a faster rate.

2. Hans Straka, PhD (Ludwig-Maximilians-University Munich, Germany):
Adaptive plasticity of locomotor efference copy signaling during development

Hans Straka will examine the adaptive plasticity of locomotor efference copy signaling during development in Xenopus. Self-generated body motion requires compensatory eye movements to stabilize visual image processing in all vertebrates. This motor behavior is traditionally ascribed to transformations of visuo-vestibular sensory signals into extraocular motor commands. In Xenopus, however, spinal central pattern generator (CPG)-derived locomotor efference copies provide a reliable, fast feedforward mechanism for gaze-stabilization during locomotion and this appears to be a dominant mechanism in tadpoles antecedent to faithful sensory encoding of angular head acceleration. In larvae, direct spino-extraocular projections produce conjugate, left-right eye rotations that counteract opposite-directed head displacements during tail-based locomotion. Findings suggest that during metamorphosis adaptive plasticity of feedforward mechanisms enable matching of spinal CPG-driven extraocular motor activity to changing requirements for image stabilization as body plan and locomotor form change.

3. Laurent Vinay, PhD (Institut de Neurosciences de la Timone, France):
The developmental sequence of neuronal and network properties in the spinal cord

Laurent Vinay will discuss the developmental sequence of neuronal and network properties in the spinal cord of mice and how this trend may generalize across the developing nervous system. A synchronized pattern of activity emerges early in the spinal cord, before the network can be driven by the brain or the periphery. This immature spontaneous activity plays a key role in both the maturation of electrical properties of neurons and the wiring within the network. The expression of immature patterns ends at about the time pathways descending from the brain become fully functional. A similar developmental sequence is observed in other brain structures such as the cortex and the striatum although the timetable of development differs.

15:00 – 15:15 **Break**

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Tuesday, April 16 *Continued*

15:15 – 17:30 **Session 3**

Motor disorders during development

Chairperson: Hans Forssberg, MD PhD

The prevalence of cerebral palsy (CP) is 2/1000 in high-resource countries. Despite the large population of people with CP worldwide, there is a lack of efficient intervention methods to improve motor function and activity. There are more than 40 alternative treatment methods, but only a few have been evaluated using the criteria of Evidence Based Medicine (www.evidence.nhs.uk/search). Of these, only three have been reported to be effective. All three are based on use-induced plasticity. This session will focus on how principles of neural plasticity derived from animal models can be translated into clinical intervention programs for children with CP.

1. Kathleen Friel, PhD (Cornell University, USA):
An animal model of unilateral CP

Kathleen Friel will discuss the underlying mechanisms of motor development and CP rehabilitation, derived from studies of an animal CP model.

2. Andrew Gordon, PhD (Columbia University, USA):
Use-induced therapy (CIMT) in children with unilateral CP

Andrew Gordon will discuss clinical research about use-induced therapy in children with unilateral CP.

3. Diane Damiano, PhD PT (National Institutes of Health, USA):
Lower limb training in children with CP

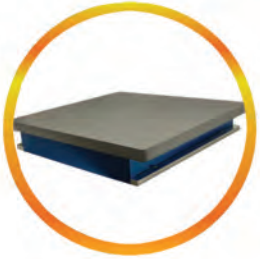
Diane Damiano will discuss locomotor training strategies in light of emerging principles of activity-induced plasticity.

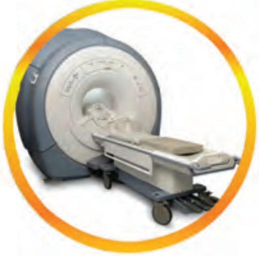
4. Hans Forssberg, MD PhD (Karolinska Institutet, Sweden):
Molecular basis of activity induced motor skill learning

Hans Forssberg will show preliminary results regarding the molecular mechanisms underlying motor skill learning.

18:00 **Opening Dinner for Annual Meeting**

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





NCM Annual Meeting Detailed Daily Schedule

NCM 23rd Annual Meeting
San Juan, Puerto Rico • April 15 – 20, 2013

All Sessions will be held in Ballroom A. Posters will be located in Ballroom B & C

Day 1 Tuesday, April 16

17:00 – 19:00 **Conference Registration**

19:00 – 21:00 **Opening Dinner**

Day 2 Wednesday, April 17

08:00 – 10:15 **Session 1, Panel I**

Modulation of motor learning with transcranial direct current stimulation: mechanisms and applications

Organizer: J. Diedrichsen

Participants: P. Celnik, B. Fritsch, J. Reis

10:15 – 10:45 **Break**

10:45 – 13:00 **Session 2, Panel II**

Interaction of auditory and vocal-motor control systems

Organizer: L. Romanski

Participants: C. Larson, J. Greenlee, X. Wang

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

Grazing Lunch

15:00 – 16:00 **Session 4, Short Perspective I**

New functions for gain-field encoding: Not just an intermediate step in coordinate transformations

Participants: M. Smith, D. Nozaki

16:00 – 17:20 **Session 5, Individual Presentations I**

An internal copy of motor commands for skilled reaching conveyed by V2a propriospinal interneurons

Participants: E. Azim, J. Jiang, S. Fageiry, B. Alstermark, T. Jessell

A trans-cerebellar motor circuit conveyed by V2a propriospinal interneurons

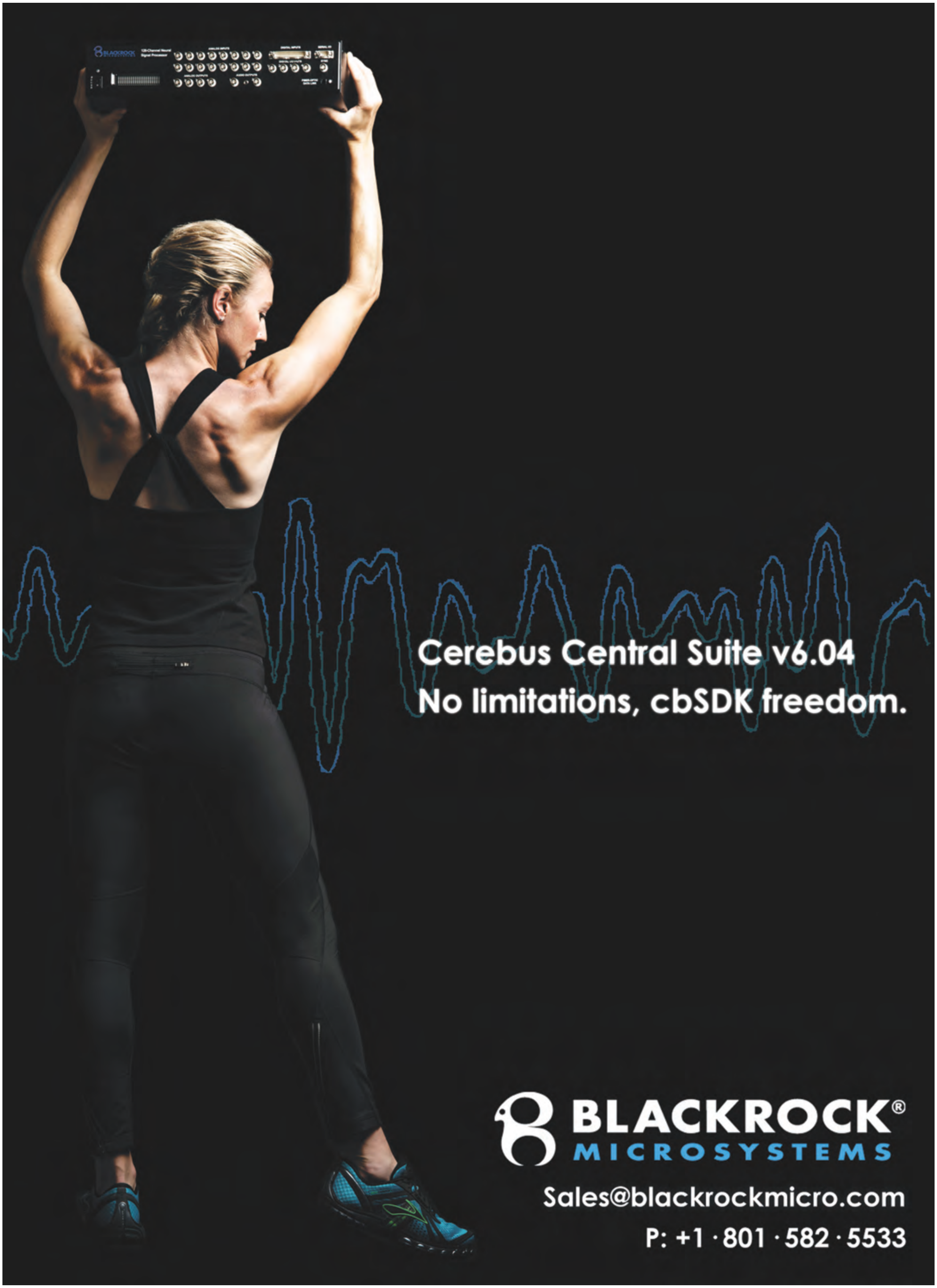
Participants: B. Alstermark, E. Azim, J. Jiang, T. Jessell

Distinct thalamo-cortical controls for shoulder, elbow, and wrist during locomotion

Participants: I. Beloozerova, V. Marlinski, E. Stout, M. Sirota

Optimizing multi-channel microstimulation pulse trains with a model-predictive controller

Participants: John S Choi, Austin J Brockmeier, Matthew Emigh, Joseph T Francis



Day 3 Thursday, April 18

08:00 – 10:15 Session 6, Individual Presentations II

Neural plasticity in vestibulo-spinal pathways after unilateral labyrinthectomy as the origin for scoliotic deformations
Participants: P. Vidal, F. Lambert, D. Malinvaud, H. Straka

Somatosensory integration and sensorimotor integration in Parkinsons disease
Participants: J. Konczak

Spatial localization abilities of a single hemisphere: a study of saccadic eye movement motor efference copy in hemidecorticate patients
Participants: K. Rath-Wilson, D.I Guitton

Saccade target selection relies on feedback competitive signal integration
Participants: J. Goossens, J. Kalisvaart, A. Noest, A. van den Berg

Probing the impact of electrical stimulation across the basal ganglia using saccades
Participants: M. Watanabe, J. J. Jantz, D. P. Munoz

Continuous updating of superior colliculus visuospatial memory responses during smooth pursuit eye movements
Participants: S. Dash, X. Yan, H. Wang, J. Crawford

10:15 – 10:45 **Break**

10:45 – 13:00 Session 7, Panel III

Neural bases of sensorimotor control of object grasping and manipulation
Organizer: J. Gallivan,
Participants: P. Janssen, M. Davare

13:00 – 15:00 Session 8, Poster 1b

Grazing Lunch

15:00 – 16:30 Session 9, Perspective Panel I

Not your father's axial system: integration of the trunk and limbs as the dynamical base of locomotion
Organizer: S. Giszter
Participants: Y. Ivanenko, A. Ijspeert, J. Cazalets

16:30 – 17:30 **Members Business Meeting**

Day 4 Friday, April 19

08:00 – 10:15 **Session 10, Individual Presentations III**

Using musculoskeletal modeling and simulation to investigate the accuracy and reliability of muscle synergies

Participants: K. Steele, M. Tresch, E. Perreault

Learned muscle synergies as prior in dynamical systems for controlling bio-mechanical and robotic systems

Participants: E. Rückert, A. d'Avella

08:00 – 10:15 **Session 10, Individual Presentations III** *continued*

A unifying framework for the identification of kinematic and electromyographic motor primitives

Participants: E. Chiovetto, A. d'Avella, M. Giese

The acquisition of hidden models in sensorimotor learning

Participants: D. Narain, P. Mamassian, E. Brenner, J. Smeets, R. van Beers

Task-level brain-machine interfaces

Participants: E. Todorov, V. Kumar, Y. Tassa

Sensorimotor reward modulation during motion and observation used to implement an actor-critic brain machine interface

Participants: J. Francis, B. Marsh , A. Tarigoppula, C. Chen

10:15 – 10:45 **Break**

10:45 – 13:00 **Session 11, Panel IV**

What have we learned from a century of studying primary motor cortex?

Organizer: M. Omrani

Participants: S. Scott, P. Cheney, M. Churchland, D. Moran, N. Hatsopoulos

13:00 – 15:00 **Session 12, Poster 2a**

Grazing Lunch

Day 5 Saturday, April 20

08:00 – 10:15 Session 13, Panel V

What can we learn from rapid online corrections about the planning and control of reaching movements?

Organizer: L. Oostwoud Wijdenes

Participants: D. Franklin, J. Kalaska, J. Nashed, A. Reichenbach

10:15 – 10:45 **Break**

10:45 – 13:00 Session 14, Individual Presentations IV

Motor learning in human development reveals distinct mechanisms of retention and savings
Participants: K. Musselman, A. Bastian

Mechanisms of motor learning: adaptation vs. skill

Participants: S. Telgen, D. Parvin, J. Diedrichsen

Role assignment in human-human motor interaction

Participants: A. Melendez-Calderon, C. Bagnato, V. Komisar, E. Burdet

Limitations of delayed feedback control suggest a forward update in state estimation following perturbations

Participants: F. Crevecoeur, S. Scott

Sensorimotor feedback based on task-relevant error robustly predicts temporal recruitment and multidirectional tuning of muscle synergies

Participants: L. Ting, S. Safavynia

10:45 – 13:00 Session 14, Individual Presentations IV *continued*

Action and goal related decision variables modulate the competition between multiple potential targets

Participants: V. Enachescu, V. Christopolous, S. Schaal

Optimal strategies for throwing at high speeds

Participants: M. Venkadesan, A. Srinivasan

13:00 – 15:00 Session 15, Poster 2b

Grazing Lunch

15:00 – 17:00 Session 16, Keynote Address

Sifting Circuits for Motor Control

Thomas M Jessell

HHMI, Kavli Institute for Brain Science, Depts. Neuroscience, Biochemistry and Molecular Biophysics, Columbia University, New York, NY

17:00 – 18:00 **Closing Drinks Reception - Ballroom Foyer**

Session 1, Panel I

Wednesday, April 17 * 08:00 – 10:15

Modulation of motor learning with transcranial direct current stimulation: mechanisms and applications

Joern Diedrichsen[1], Pablo Celnik[2], Brita Fritsch[3], Janine Reis[3]

[1]University College London, [2]Johns Hopkins University, [3]Albert Ludwigs University Freiburger

Within the past decade, several behavioral studies have demonstrated positive effects of transcranial direct current stimulation (tDCS) on motor performance, skill learning and adaptation in healthy subjects and stroke patients. The panel will present new results that provide some insights into the mechanisms behind these effects. Apart from its practical potential for rehabilitation of motor disorders, we will also discuss the utility of the technique to obtain a deeper understanding of the mechanisms of motor learning in the healthy brain. Brita Fritsch will give an update on the biological mechanisms behind tDCS. This introductory talk will summarize recent results from in-vitro and in-vivo animal studies that provide insight into the mechanisms underlying tDCS. The polarity-dependent modulation of cortical excitability, the effects of DCS on synaptic strength and the molecular mechanisms of DCS-induced long term potentiation will be explained and novel results on safety aspects of tDCS discussed. Pablo Celnik will focus on the use of tDCS to study cerebellar contributions to motor learning. He will show that it is possible to modulate and measure cerebellar excitability in humans. He will then present a series of recent studies that show how this manipulation of cerebellar excitability affects hand and locomotor learning. Jörn Diedrichsen will then shift the focus to the effects of tDCS applied to the primary motor cortex. He will show how tDCS changes the representation of skill in the two cortical hemispheres. As Janine Reis', his results demonstrate that different tDCS montages not only differ in their efficacy with which they promote learning, but also influence how the acquired skill transfers to the untrained hand. Using functional imaging and pattern analysis, he will then show how the distribution of skilled representations is influenced by the hand that was trained and by the polarity of the stimulation over contra- and ipsilateral motor cortex. Janine Reis will complete the panel by talking about the effects of tDCS applied to the motor cortex on visuomotor skill learning in healthy individuals and stroke patients. She will show that anodal tDCS combined with prolonged motor training can improve visuomotor skill learning, and that tDCS specifically augments different temporal components of the learning process. Her novel results support the idea that tDCS interacts both with skill acquisition (within session) and memory consolidation (between session) in a time dependent fashion. Because tDCS has tremendous potential to improve motor learning after a stroke, she will also contrast the effects of tDCS on motor skill learning in healthy individuals, and in stroke patients across the recovery process and highlight possible implications for the design of treatment strategies.

Session 1, Panel II

Wednesday, April 17 • 10:45 – 13:00

Interaction of auditory and vocal-motor control systems

Lizabeth Romanski[1], Chuck Larson[2], Jeremy Greenlee[3], Xiaoqin Wang[4]

[1]University of Rochester School of Medicine, [2]Northwestern University [3]University of Iowa, [4]Johns Hopkins University

Within the past decade, several behavioral studies have demonstrated positive effects of transcranial direct current stimulation (tDCS) on motor performance, skill learning and adaptation in healthy subjects and stroke patients. The panel will present new results that provide some insights into the mechanisms behind these effects. Apart from its practical potential for rehabilitation of motor disorders, we will also discuss the utility of the technique to obtain a deeper understanding of the mechanisms of motor learning in the healthy brain. Brita Fritsch will give an update on the biological mechanisms behind tDCS. This introductory talk will summarize recent results from in-vitro and in-vivo animal studies that provide insight into the mechanisms underlying tDCS. The polarity-dependent modulation of cortical excitability, the effects of DCS on synaptic strength and the molecular mechanisms of DCS-induced long term potentiation will be explained and novel results on safety aspects of tDCS discussed. Pablo Celnik will focus on the use of tDCS to study cerebellar contributions to motor learning. He will show that it is possible to modulate and measure cerebellar excitability in humans. He will then present a series of recent studies that show how this manipulation of cerebellar excitability affects hand and locomotor learning. Jörn Diedrichsen will then shift the focus to the effects of tDCS applied to the primary motor cortex. He will show how tDCS changes the representation of skill in the two cortical hemispheres. As Janine Reis', his results demonstrate that different tDCS montages not only differ in their efficacy with which they promote learning, but also influence how the acquired skill transfers to the untrained hand. Using functional imaging and pattern analysis, he will then show how the distribution of skilled representations is influenced by the hand that was trained and by the polarity of the stimulation over contra- and ipsilateral motor cortex. Janine Reis will complete the panel by talking about the effects of tDCS applied to the motor cortex on visuomotor skill learning in healthy individuals and stroke patients. She will show that anodal tDCS combined with prolonged motor training can improve visuomotor skill learning, and that tDCS specifically augments different temporal components of the learning process. Her novel results support the idea that tDCS interacts both with skill acquisition (within session) and memory consolidation (between session) in a time dependent fashion. Because tDCS has tremendous potential to improve motor learning after a stroke, she will also contrast the effects of tDCS on motor skill learning in healthy individuals, and in stroke patients across the recovery process and highlight possible implications for the design of treatment strategies.

Session 4, Short Perspective I

Wednesday, April 17
15:00 – 16:00

New functions for gain-field encoding: Not just an intermediate step in coordinate transformations

Maurice Smith[1], **Daichi Nozaki**[2]

[1]Harvard University, [2]University of Tokyo

Gain field encoding is generally thought of as the neural mechanism for the intermediate step in transforming spatial information between extrinsic and intrinsic reference frames for action planning in the sensorimotor system. However, exciting recent work shows that this key neural mechanism may have much farther-reaching computational significance than previously thought. This session will highlight the implications of widespread gain field encoding, bringing together recent work in human motor control and neuroimaging showing that multiplicative gain field encoding underlies not only the process of coordinate system transformations but also the internal representations of motor memories and action planning. Maurice Smith will show that the memories underlying visuomotor learning are based on a multiplicative gain field combination of action representations in intrinsic and extrinsic coordinates. This challenges previous ideas suggesting that motor learning may be associated with a single coordinate system or that separable intrinsic and extrinsic learning may coexist, by showing that the generalization of visuomotor learning is simultaneously local in intrinsic and extrinsic coordinates in a pattern dutifully predicted by a gain field combination of intrinsic and extrinsic generalization. We will show evidence that the internal representations of bimanual movements are based on a multiplicative gain field combination of single-limb representations. Nozaki will show that novel physical dynamics experienced during bimanual reaching movements are learned as a gain field combination of left arm and right arm representations, displaying generalization patterns that show clear gain field tuning. He will go on to show that an understanding of this gain field representation allows for the design of training paradigms that can efficiently train a variety of different intermanual coordination patterns in force field adaptation. We will show evidence for multiplicative gain field encoding in neural representations of bimanual finger movements in motor cortex. He will show that this gain field representation of bimanual movements is located on the crest of the central sulcus, in the transitionary zone between primary motor cortex and premotor cortex, whereas the representation of simpler unimanual movements is located in the depth of the sulcus. Together, these findings suggest that the mechanism of multiplicative gain field encoding has broad computational significance in the motor system. One key aspect of this significance is the ability of multiplicative gain field encoding to provide a mechanism for combinatorial encoding across multiple features. Computer scientists and electronics engineers who deal with digital systems view the operation of multiplication as a logical AND - which represents the nonlinear combination of inputs that groups them together. For more continuous signals like those associated with spatial representations, multiplication effectively performs a soft grouping that we propose has widespread computational import in the nervous system.

Session 5, Individual Presentation I

Wednesday, April 17
16:00 – 17:20

An internal copy of motor commands for skilled reaching conveyed by V2a propriospinal interneurons

Eiman Azim[1], Juan Jiang[2], Samaher Fageiry[1], Bror Alstermark[2], Thomas Jessell[1]

[1]Columbia University, [2]Umeå University

Skilled forelimb reaching is a refined motor behavior that exhibits considerable conservation across terrestrial mammals. Studies in cats and primates have suggested a modular organization to forelimb motor control, with cervical propriospinal neurons (PNs) contributing to reaching behavior, but not to other elements of forelimb movement (Alstermark & Isa, 2012). Cervical PNs receive convergent input from multiple descending systems, and extend bifurcating axons. One PN axonal branch projects caudally to forelimb motor neurons (MNs), and the other extends rostrally to the lateral reticular nucleus (LRN), which relays information to the cerebellum. Their dual output raises the possibility that PNs convey an internal copy of motor commands to cerebellar processing centers. Testing this general idea has been hindered by the difficulty in manipulating putative internal copy pathways in a selective enough manner to permit analysis of their roles in motor coordination. We have used genetic and viral tools in the mouse, together with kinematic analyses of reaching, to investigate the contribution of the cervical PN internal copy pathway to skilled forelimb movement. Using in vivo electrophysiology and a combination of retrograde and trans-synaptic labeling from MN and LRN axonal targets, we show that mouse PNs exist, and resemble their cat and primate counterparts. The known anatomical and physiological features of cervical PNs suggested that they are included within the ipsilaterally-projecting, excitatory V2a interneuron (IN) subclass, defined by expression of the transcription factor Chx10. Indeed, combined genetic and AAV-FLEX viral tracing in Chx10-Cre mice revealed that ~30% of cervical V2a INs correspond to PNs. To analyze reaching we examined forelimb movement in control mice using a high-resolution kinematic assay. Normal reaches were stereotyped with little difference in the trajectory or velocity of successful and unsuccessful reaches. Elimination of > 80% of cervical V2a INs with diphtheria toxin elicited defects in early reach trajectory and velocity, but not in pronation and digit extension, nor in forelimb locomotion. These data show that cervical V2a INs control reach accuracy but not more distal digit movements. However, our ablation affected the PN and non-PN subsets of V2a INs, and both premotor and LRN axonal branches of PNs. To confine our analysis to the PN internal copy pathway, we used a viral optogenetic strategy to express Channelrhodopsin-2 in cervical V2a INs, and restricted photoactivation to PN axons entering the LRN. Exposure of PN axons to light excited pre-cerebellar LRN neurons without eliciting antidromic spiking in PNs, permitting selective access to the rostral PN axonal pathway. Photoactivation of these V2a PN axons severely affected reaching trajectories, eliciting movement errors and fluctuations in velocity. This perturbation of motor control involves cerebellar systems since forelimb MN field potentials induced by PN axon photoactivation were abolished by lesioning LRN cerebellar afferents. Thus, the rostral PN projections may influence motor output via an LRN-cerebellar-bulbospinal circuit. By matching an internal copy to motor commands, cervical PNs appear to engage a cerebellar pathway that modulates motor output and ensures the fidelity of skilled reaching. (See abstract: Trans-cerebellar motor circuit conveyed by V2a propriospinal interneurons, Alstermark, Azim, Jiang, Jessell).

A trans-cerebellar motor circuit conveyed by V2a propriospinal interneurons

Bror Alstermark[1], Eiman Azim[2], Juan Jiang[1], Thomas Jessell[2]

[1]Umea University, [2]Columbia University

The motor command for visually guided reaching can be mediated via a subtype of spinal interneurons, denoted C3-C4 propriospinal neurons (PNs), that project to both forelimb motoneurons (MNs) and to neurons in the pre-cerebellar Lateral Reticular Nucleus (LRN) as shown in the cat, monkey (Alstermark & Isa, 2012) and in the mouse (see abstract at this meeting; An internal copy of motor commands for skilled reaching conveyed by V2a propriospinal interneurons. Azim, Jiang, Alstermark, Jessell). The LRN is a major mossy fiber input from spinal motor centers to the cerebellum and monitors the activity of the interneurons. The branching axonal projections from the PNs to forelimb MNs and the LRN have been suggested to provide the cerebellum with an internal copy of the motor command for reaching and this hypothesis was corroborated in the mouse using optogenetic modification of V2a INs and selective photoactivation of PN axon terminals in the LRN. The results showed marked movement errors in reaching trajectory following photoactivation of the LRN neurons during reaching. To determine whether activation of PN inputs to the LRN engaged a cerebellar-motor loop, we examined MN field potentials in forelimb segments before and after lesioning LRN mossy fiber input to the cerebellum. This lesion did not affect the LRN neurons, but only their axons. The experiments were performed in fully anaesthetized mice. Extracellular recordings were made from LRN neurons and forelimb motor nuclei in the same animal. We found that photoactivation elicited large MN field potentials, which were significantly diminished following lesion of the inferior cerebellar peduncles. The PNs receive strong excitatory input from reticulospinal neurons, which in turn are excited from the deep cerebellar nuclei. The present results thus suggest that ascending PN terminals affect motor output via an LRN-cerebellar-bulbospinal circuit.

Distinct thalamo-cortical controls for shoulder, elbow, and wrist during locomotion

Irina Beloozerova[1], Vladimir Marlinski[1], Erik Stout[1], Mikhail Sirota[1]

[1]Barrow Neurological Institute

Segments of the limb differ in their mechanical characteristics, such as dimensions and weight, and in their role during movements. While several lines of evidence suggest that different limb segments are controlled differently by the nervous system, these distinctions have been never explicitly studied before at the level of single neurons. Here we present our recent data on differential controls for the shoulder, elbow, and wrist exerted by neurons in the thalamo-cortical network during locomotion. All data were collected from chronically instrumented cats walking on a flat surface (simple locomotion) and along a horizontal ladder (complex locomotion). The activity of motor cortex neurons that project to the pyramidal tract (PTNs), of neurons of the motor ventrolateral thalamus (VL), most identified as projecting to the motor cortex (TCs), and of neurons of the motor compartment of the reticular nucleus of the thalamus (RE), which inhibit TCs, were recorded. Neurons in each of the motor centers were grouped according to their receptive field as shoulder-, elbow-, and wrist/paw-related. The discharges of these subpopulations within and between each of the motor centers were compared across the step cycle of simple and ladder locomotion. Significant differences were found in all comparisons. During simple locomotion, shoulder-related PTNs were most active in late stance and early swing, and upon transition to ladder locomotion, often increased discharge rate and step-related frequency modulation while reducing discharge duration. Elbow-related PTNs were most active during late swing and early stance, in a phase opposite to that of shoulder-related cells, and typically did not change activity, modulation, or duration of the discharge on the ladder. Wrist-related PTNs were most active during swing, and upon transition to ladder locomotion often decreased activity and discharge duration while increasing frequency modulation. Each of VL groups, including TCs, was active largely in anti-phase with their PTN counterparts. Shoulder-related VL cells were more active during the transition from swing to stance. Elbow-related cells tended to be more active during transition from stance to swing and on the ladder often decreased activity and increased modulation. Wrist-related neurons were more active throughout the entire stance phase. In the RE, which inhibits TCs, shoulder-related neurons had low discharge rates and depths of modulation and their long periods of activity were distributed across the cycle, clustering largely in-phase with those of shoulder-related TCs. In sharp contrast, wrist-related RE cells discharged synchronously during end of stance and swing phase with short periods of high activity and modulation. Their activity coincided with a decrease in the activity of wrist-related TCs. Thus, only the strongest ascending signals related to the distal limb could reach the motor cortex from the thalamus thereby allowing other inputs to the motor cortex to gain a greater contribution to the formation of the motor cortex output during this period of the stride. We conclude that thalamo-cortical network processes information related to different segments of the forelimb differently and exerts distinct controls over the shoulder, elbow, and wrist during locomotion.

Optimizing multi-channel microstimulation pulse trains with a model-predictive controller

John Choi[1], Austin Brockmeier[2], Matthew Emigh[2], Joseph Francis[1]

[1]SUNY Downstate Medical Center, [2]University of Florida

Next-generation limb prosthetics might provide subjects with feedback about external stimuli, perhaps originating from sensors on an artificial limb, by directly stimulating the CNS. Recently, there has been interest in optimizing stimulus encoding schemes that excite sensory neural populations in a way that produces naturalistic sensations. One strategy is to numerically compute multichannel current waveforms that, according to a mathematical model, reproduce a target neural response as closely as possible. We demonstrate the use of this framework for optimizing extracellular stimulation in the thalamocortical system of the anesthetized rat. To model the effects of our stimulus inputs on the affected region, we implanted electrode arrays in VPL thalamus and the analogous area in primary somatosensory (S1) cortex. As a modeling sequence, we stimulated with a known random pulse sequence for 5 minutes in VPL while recording the local field potentials (LFP) in downstream S1. We then trained a linear dynamical model to this input-output data. Using a model-predictive control (MPC) strategy, we computed the stimulation sequences that mimicked (in a squared-error sense) the responses observed in cortex during natural touch stimuli. These electrical pulse sequences successfully recreated naturalistic temporal features e.g. onset/offset amplitude, RMS response power of the cortical response. Interestingly, they also preserved the natural spatial arrangement of response peaks across different touch locations. For any given touch site, the optimization resulted in sequences that, for the most part, injected current through 2-4 electrode configurations with amplitudes below 24 microamperes per phase. For any given "virtual touch," the strongest burst of pulses occurred 6-8ms following touch onset. Our work represents a preliminary in-vivo demonstration of what could be a way of developing stimulation paradigms that achieve biomimetic "write-in" of sensory information.

Session 6, Individual Presentations II

Thursday, April 18
08:00 – 10:15

Neural plasticity in vestibulo-spinal pathways after unilateral labyrinthectomy as the origin for scoliotic deformations

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Adolescent idiopathic scoliosis in humans is often associated with vestibulo-motor deficits. Compatible with a vestibular origin, scoliotic deformations were provoked in adult Xenopus frogs by unilateral labyrinthectomy (UL) at larval stages. We hypothesize that the induction of skeletal deformations after UL depends on a manifested asymmetric activity in descending vestibulo-spinal pathways in the absence of body weight-supporting limb proprioception. To test this hypothesis, we examined the causality between morpho-physiolocial alterations at cellular and network levels and the peripheral vestibular lesion in larval Xenopus. As a result, spinal motor nerves that were modulated by the previously intact side before UL remained silent during natural vestibular stimulation after the lesion. In addition, retrograde tracing of hindbrain descending pathways revealed a significant neuronal loss of ipsilesional crossed vestibulo-spinal projections. This loss facilitates a general mass imbalance in descending premotor activity and a permanent asymmetric motor drive to the axial musculature. Consequently, we propose that the persistent asymmetric contraction of trunk muscles exerts a constant, uncompensated differential mechanical pull on bilateral skeletal elements, which enforces a distortion of the soft cartilaginous skeletal element and bone shapes. This finally provokes severe scoliotic deformations during the ontogenetic development similar to the human syndrome.

Somatosensory integration and sensorimotor integration in Parkinson's disease

Juergen Konczak[1]

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Parkinson's disease (PD) is a neurodegenerative disease affecting the basal ganglia and leads to characteristic motor symptoms of slowness, tremor, rigidity and abnormal posture. While these deficits are the main concern of PD patients, clinical research within the last decade documented that the disease is also associated with impairments in somatosensory function, such as decreased kinaesthesia, tactile, haptic, pain and temperature perception. However, while the significance of a decreased pain or temperature perception is easily understood, the relevance of a decrease in proprioceptive and haptic precision for sensorimotor function has been difficult to discern. In this talk I will first outline our current state of knowledge on somatosensory dysfunction in PD. Specifically I will present data from my group and others on how psychophysical thresholds for position, motion and haptic sensing are altered by the disease. Then I report on our recent work showing that pharmacological intervention and deep brain stimulation can only partially restore this function. Finally I will discuss computational models that attempt to explain these deficits as a failure of multimodal somatosensory integration (Konczak et al. 2012). I will argue that that PD affects early stages of somatosensory integration that ultimately have an impact on processes of sensorimotor integration. We found no evidence suggesting that internal feedback mechanisms involving sensorimotor integration are affected by PD. This is not to say, sensorimotor integration per se is not affected. However, our results suggest that the known motor problems in PD that are generally associated as a failure of sensorimotor integration may, in fact, have a sensory origin.

Spatial localization abilities of a single hemisphere: a study of saccadic eye movement motor efference copy in hemidecorticate patients

Kate Rath-Wilson[1], Daniel Guitton[1]

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It is usually assumed that a single hemisphere controls eye saccades directed contralateral to it; but in hemispherectomy patients the single hemisphere can generate accurate saccades to the left and right. The present research program is directed to understanding whether the single hemisphere can monitor, via a corollary discharge signal (CD), its own self generated eye movements. We have shown elsewhere that hemidecorticate subjects are able to monitor the vectorial displacement of the eyes during smooth pursuit eye movements in either direction. Since smooth pursuit is believed to be controlled by the ipsilateral hemisphere, it is surprising that these subjects are able to monitor bilaterally-directed smooth pursuit. In the present study, we sought to determine whether the hemidecorticate brain is also capable of generating and interpreting CD signals for bilateral saccades. Saccades are believed to be controlled by the contralateral hemisphere and the literature suggests that lesions of the frontoparietal areas cause marked deficiencies in monitoring contralesionally-directed saccades. By using a double-step saccade paradigm, adapted for our subjects' hemianopia, we show here that one hemisphere can monitor a previous left or right saccade and use this information to plan and generate subsequent saccades, all in the dark. We used two sets of tasks. The first, double-step exogenous, required the subjects to fixate the fixation point (FP) while two targets flashed in succession in the seeing field. Subjects were required to wait until FP was extinguished, and then, in the dark, to look to the remembered locations of the targets. With this task, we were able to determine that our subjects could perform a contra-contra task (two successive saccades contralateral to the remaining hemisphere) and a contra-ipsi task (one saccade contralateral and a second saccade ipsilateral to the remaining hemisphere and into the blind field). In both tasks, they were required to monitor their first saccade and use this information to make an accurate second saccade, which they could. The second type of task, double-step endogenous, involved flashing only a single target (T) in the seeing hemifield. Subjects were instructed to first make a random saccade either into their blind field, past T, or to a location in the seeing field between T and FP. They were then required to make a second saccade to the remembered location of T. This type of task allowed us to determine if our subjects could monitor self-generated, non-goal-directed saccades, to either their blind (contralesional) or seeing (ipsilesional) hemifields. We expected the former task to be most difficult since previous studies have found that even small lesions in the frontoparietal region can cause marked deficits in contralesional saccade monitoring. While the performance of our patients was significantly worse than controls, they were surprisingly better than patients with discrete unilateral frontoparietal lesions performing similar tasks. These findings suggest that further research into the relationship between performance and the extent of the lesion should be conducted; it is possible that larger cortical lesions induce greater plasticity in remaining brain areas, an idea that could have profound clinical implications.

Saccade target selection relies on feedback competitive signal integration

Jeroen Goossens[1], Joke Kalisvaart[1], André Noest[2], Albert van den Berg[1]

[1]Radboud University Nijmegen Medical Centre, [2]Utrecht University

It is often assumed that decision-making involves neural competition, accumulation of evidence 'scores' over time, and commitment to a particular alternative once its 'scores' reach decision-threshold first. So far, however, neither the first-to-threshold rule, nor the nature of competition (feed-forward or feedback inhibition), has been revealed by experiments. Here, we presented two simultaneously-flashed targets that reversed their intensity difference during each presentation, and instructed subjects to make a saccade towards the brightest target. All subjects preferentially chose the target that was brightest during the first stimulus phase. Unless this first phase lasted only 40 ms, primacy persisted even if the second, reversed-intensity phase lasted longer. This effect did not result from premature commitment to the initially-dominant target; a strong target imbalance in the opposite direction later on drove nearly all responses towards that location. Moreover, there was a non-monotonic relation between primacy and target imbalance; increasing this imbalance beyond 40 cd/m2 caused an attenuation of primacy. These are the hallmarks of hysteresis, predicted by models in which target-representations compete through strong feedback. Reaction times were independent of the choice-probability. These results contradict theories which propose a first-to-threshold decision rule for saccadic choice behavior.

Probing the impact of electrical stimulation across the basal ganglia using saccades

Masayuki Watanabe[1], Jay J. Jantz[1], Doug Monoz[1]

[1]Queen's University

Electrical stimulation has been delivered to the basal ganglia to treat intractable symptoms of a variety of neurological and psychiatric disorders (e.g., Parkinson's disease and depression). However, it is still unknown how such treatments improve behavioral symptoms. A difficulty of this problem is that artificial signals created by electrical stimulation interact with intrinsic signals generated within inherent neural circuits before influencing behavior, thereby making it important to understand how such interactions between artificial and intrinsic signals occur. We addressed this issue by analyzing the effects of electrical stimulation under the following two behavioral conditions that induce different states of intrinsic signals: (1) subjects behave spontaneously without task demands; (2) subjects perform a behavioral paradigm purposefully. We analyzed saccade eye movements in monkeys while delivering microstimulation to the output [substantia nigra pars reticulata (SNr)] and the input [caudate nucleus (CN); subthalamic nucleus (STN)] stages of the basal ganglia. Microstimulation delivered to the output structure (SNr) biased the endpoints of spontaneous saccades toward the ipsilateral direction of stimulation sites. Furthermore, the same microstimulation created overall ipsilateral biases in purposive saccades by suppressing contralateral saccade initiation during a prosaccade (look toward a visual stimulus) or an antisaccade (look away from a stimulus) paradigm. In contrast, in the input structures (CN and STN), microstimulation biased spontaneous saccades toward the contralateral direction. However, it suppressed purposive (pro/anti) saccades toward both contralateral and ipsilateral directions. These results suggest that artificial signals delivered to the output structure of the basal ganglia (SNr) influence behavior more directly without receiving strong modification by intrinsic signals. However, the impact of electrical stimulation in the input structures (CN and STN) changes dynamically depending on the state of intrinsic signals that vary under a variety of behavioral demands in everyday life.

Continuous updating of superior colliculus visuospatial memory responses during smooth pursuit eye movements

Suryadeep Dash[1], Xiogang Yan[1], Hongying Wang[1], John Crawford[1]

[1]Center for Vision Research, York University

Spatial updating is a process that enables us to constantly compute spatial relationships between ourselves and the surrounding environment during self-motion. Primates are able to spatially update saccade targets across intervening saccade or smooth pursuit (SP) eye movements. Various studies have demonstrated discrete remapping of visual responses, in several brain structures, before and after the saccade. However, no study to date has shown continuous updating of such responses during the eye movement. In this study we recorded superior-colliculus (SC) unit activity from 2 monkeys. Animals were trained to spatially update the location of a saccade target across an intervening SP. Neurons were characterized (as visual (n=63), visuomotor (n=64) or motor neurons (n=9)) and their visual / motor receptive fields (RF) were specified using a memory saccade paradigm. After this each neuron was tested in the SP-saccade paradigm. Every neuron that showed a visual response, whether it was a visual and visuomotor neuron, exhibited a clear and robust modulation in activity when the location of remembered target passed across the RF of the neuron during SP. We then conducted a supplemental experiment with a modified version of the task in which 2 targets (white and orange) were shown simultaneously. Only saccades to the white target were rewarded, so animals learned to ignore the orange target within 1 week of training. Every neuron that showed a visual response (n=46), whether it was a visual and visuomotor neuron, exhibited a clear and robust modulation in activity when the location of behaviorally relevant target passed across the RF of the neuron during SP. In contrast, the response was either absent or significantly weaker when the location of the ignored target corresponded with the RF during SP. In summary, we found that the SC visual memory response is continuously updated during SP eye movements. We also found that only visual responses (not motor) are involved in this updating response, but still the response is strongly influenced by saccade target selection. We suggest that this response may reflect a general mechanism for continuous updating visuospatial memory for action in gaze-centered coordinates during various types of slow self-motion.

Session 7, Panel III

Thursday, April 18
10:45 – 13:00

Neural bases of sensorimotor control of object grasping and manipulation

Jason Gallivan[1], Peter Janssen[2], Marco Davare[3]

[1]Queen's University, [2]University College London, [3]K.U. Leuven

Skilled grasping requires the brain to extract extrinsic visual signals of the target object, like its size and shape, and transform this sensory information into motor commands that coordinate actions of the hand and digits. Once an object has been grasped, additional mechanisms, such as the prediction of intrinsic object properties like weight, are required for effective lifting and further manipulation. How is object grasping and manipulation encoded both at the level of cortical output neurons and single brain areas? What key cortical structures are involved? How is information related to the extrinsic and intrinsic properties of objects transferred between brain areas and, more generally, how do neural populations across the whole of cortex work together to produce skilled object manipulation. Adopting a multi-disciplinary approach that combines evidence from neural recording methods in non-human primates to transcranial magnetic stimulation (TMS) and functional magnetic resonance imaging (fMRI) in humans, this team presentation addresses many of these fundamental questions by considering the full range of neural activity, from the level of single neurons to cortico-cortical interactions and full-brain networks. Roger Lemon will talk about grasp specificity in premotor and motor cortex output neurons recorded from awake behaving monkeys and will compare responses in these neurons during active execution and during action observation. This work provides some rich clues as to which features of corticospinal activity are important for the generation of movement, and which for motor rehearsal/imagery and related processes. Peter Janssen will talk about the visual response properties of grasping-related neurons in macaque parietal (area AIP) and premotor (area F5a) cortex studied using single-cell recordings in monkeys during visually guided grasping. The stimuli included three-dimensional surfaces and videos of grasping actions. This work sheds light on the role of AIP and F5a in object coding and online visual control during grasping. Marco Davare will talk about human TMS studies probing corticospinal excitability (CSE) while subjects grip and lift objects in a virtual reality environment. This work shows rapid changes in CSE following lifts that contained a conflict between vision and touch. These findings demonstrate how the sensorimotor system biases the mapping between visual cues and sensorimotor memories for weight to implement fast corrective mechanisms for action control. Jason Gallivan will talk about human fMRI studies examining the coding of planned grasp and lifting actions in frontoparietal and occipitotemoral cortex. This work explores how and where in the brain knowledge about object weight, used when lifting, is represented and where signals related to object weight and material become integrated once object weight can be reliably predicted based on material. Taken together, this work indicates that object grasping and manipulation necessitates a complex interplay between the mechanisms involved in object perception, motor control, cognition and memory, and sheds new light on how brain areas located in the motor-related 'dorsal' frontoparietal cortex and perception-related 'ventral' occipitotemporal cortex are integrated into a dynamic network for controlling object-directed action. t

Session 9, Perspective Panel I

Thursday, April 18
15:00 – 16:30

Not your father's axial system: Integration of the trunk and limbs as the dynamical base of locomotion

Simon Giszter[1], Yuri Ivanenko[2], Auke Ijspeert[3], J. Cazalets[4]

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The evolution of terrestrial locomotion added limbs onto a very flexible trunk driven by distributed pattern generation along its length. However, historically, the motor control community has often viewed the trunk as a rigid body 'ground' for limb motion, and this view has also influenced robotics and vice versa. In sports and martial arts the role of 'core' strength or 'hara' is viewed as central to good performance, but is such core skill the creation of a more rigid block, or the more efficient use of the very high degrees of freedom of the complex articulated linkage and muscular hydrostat? Recently, in both robotics, rehabilitation and in basic motor control views of the control of trunk, and its role in stabilizing and coordinating locomotion have undergone a renaissance. In our perspective panel the participants will discuss new data from each laboratory considering axial control issues. We will emphasize the importance of trunk compliance and control in designing self stabilizing and efficient quadruped robots (Auke Ijspeert), in allowing function in rats with completely severed spinal cords following robot rehabilitation (Simon Giszter), and in the development of bipedal support and the maturation of the spinal segmental system in children through early maturation (Yuri Ivanenko). The trunk musculature have some of the highest spindle counts, indicating significant monitoring and use of feedback. The importance of considering compliant trunk control in designing functionally effective robots, in understanding pattern generation, in voluntary skilled motion, and in interpreting compensation and adaptations of limb motion in humans and in animal models of clinical deficits will be argued. The panel participants' data and discussions may help illuminate the different issues involved. In the spinal cord injury field, reported recovery of function result recently stirred up a controversy around the relative roles of different components of the central nervous system and neuromechanical system in achieving function following robotic rehabilitation (Van den Brand et al., 2012, Slawinska et al. 2012, Courtine et al. 2012). We will discuss trunk control in light of these concernst

Session 10, Individual Presentations III

Friday, April 19
08:00 – 10:15

Using musculoskeletal modeling and simulation to investigate the accuracy and reliability of muscle synergies

Katherine Steele[1], Matthew Tresch[1], Eric Perreault[2]

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Matrix factorization algorithms (MFAs) have traditionally been used to investigate the structure and composition of muscle synergies. These algorithms identify muscle synergies, a weighted set of co-activation between muscles, which are hypothesized to reflect a simplified underlying neuromuscular control strategy. However, it is unclear if these synergies are representative of the underlying control strategy or if they are a reflection of the biomechanics, methods, or some other constraint (Kutch 2012). The aim of this study was to investigate the ability of MFAs to accurately identify muscle synergies when the synergies are known. To investigate this aim, we used musculoskeletal modeling which enabled us to specify a synergy-based control strategy, solve for muscle activations, apply MFAs, and compare estimated synergies to specified synergies. We used a previously developed musculoskeletal model of the upper-extremity with thirty muscles and four degrees of freedom (Holzbaur 2005). We recreated the experimental protocol of an isometric upper-extremity task that has previously been used to investigate muscle synergies (Roh 2012). To specify a muscle synergy based control strategy we specified randomly generated synergies and created an algorithm to solve for muscle activations that minimized the activation level of each synergy. Thus, if muscle activation = W * c where W is a matrix of muscle synergies and c are the activation coefficients of the synergies, we minimized c squared. The musculoskeletal model and optimization algorithm were implemented using OpenSim, an open-source biomechanics modeling platform (Delp 2007). The muscle activations determined from the musculoskeletal model were used to estimate the underlying muscle synergies using a variety of common MFAs. The estimated muscle synergies were compared to the specified synergies by calculating the similarity as the average correlation coefficient. The similarity was normalized from zero to one based upon the similarity expected by chance (Tresch 2006). We also calculated the similarity of synergies calculated from activations generated from random W and c matrices without a biomechanical model. The results of this analysis indicate that MFAs could not accurately identify the underlying synergies. The average similarity of estimated and specified synergies was 0.38 (0.12). The non-negative matrix factorization algorithm had the greatest average similarity, 0.50 (0.12). Without a biomechanical model, the similarity of specified and estimated synergies was significantly greater for all MFAs, 0.64 (0.09). This value is less than a previous study (Tresch 2006) which performed a similar analysis without a biomechanical model because our analysis included more synergies and more muscles. The poor similarity between the estimated and specified synergies with a biomechanical model suggests that biomechanical constraints of the task negatively impact the ability of MFAs to correctly identify the underlying control strategy. Evaluating the accuracy and limitations of using MFAs to identify muscle synergies will help us create better strategies for understanding the underlying control strategies of movement and assist with future experimental design. Acknowledgement: This work was supported by NIH K12 HD073945.

Learned muscle synergies as prior in dynamical systems for controlling bio-mechanical and robotic systems

Elmar Rückert[1], Andrea d'Avella[2]

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One salient feature of human motor skill learning is the ability to exploit similarities across related tasks. In biology a common hypothesis for re-using shared knowledge are muscle synergies or a coherent activation of a group of muscles. Studies of human motor behavior have shown that a rich set of complex motor skills can be generated by a combination of a small number of such shared muscle synergies. For motor skill learning on the other hand a popular approach are dynamic movement primitives. This machine learning approach has many advantages, e.g. it implements a stable attractor system that facilitates learning and it can be used in high-dimensional continuous spaces. However, it does not allow for re-using shared knowledge. For each task an individual set of parameters has to be learned. We propose a novel movement primitive representation that implements muscle synergies in the form of parametrized basis functions. For each task a combination of such muscle synergies modulates a stable dynamical system. This allows for a compact representation of multiple motor skills while preserving efficient learning in high-dimensional continuous systems. The dynamic movement primitive approach can be modeled as special case in our formulation, where discrete and rhythmic movements can be represented. We demonstrate in complex humanoid walking experiments that learning multiple skills modelling walking patterns with different step heights is more robust (i.e. good solutions are found reliably) and more efficient (i.e. with fewer samples) compared to single-task learning. Furthermore, the proposed movement primitives are also used to learned muscle excitation patterns for controlling a bio-mechanical model of a human arm with six muscles.

A unifying framework for the identification of kinematic and electromyographic motor primitives

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Many studies in recent years have shown that the kinematic and electromyographic patterns underlying complex movements can be approximated by the combinations of a small number of components, also referred to as motor synergies or motor primitives. The identification of such components has typically been carried out by applying different unsupervised learning algorithms, such as principal or independent component analysis (PCA and ICA respectively) and non-negative matrix factorization (NMF). While classical ICA, PCA and NMF are based on instantaneous mixture models (Chiovetto et al. 2010, 2012; Dominici et al. 2011), linearly combining a set of basis vectors, more advanced techniques have also been proposed that include the estimation of temporal delays of the relevant mixture components (d'Avella et al. 2003, 2006; Omlor and Giese 2011). However, the availability of different algorithms may complicate the comparison and interpretation of the results obtained in different studies. We propose a unifying framework for the description of motor primitives and a new algorithm for their identification developed according to this framework. We show how all the different definitions of time-invariant and time-varying synergies given in the literature can be derived from one single generative anechoic mixture model which relies on the linear combination of synergies that can be shifted in time. When the delays of the primitives are all set to zero, for instance, the anechoic model reduces to the classical instantaneous linear combination models underlying the definition of synchronous or temporal synergies usually identified by standard ICA, PCA or NMF. Similarly, when specific equality or positivity constraints are imposed on its meters, the model can develop into the classical model describing a time-varying synergistic organization of the data (d'Avella et al. 2003, 2006). We demonstrate how, by embedding of smoothness prior in the underlying generative model, the algorithm can identify, from a given data set, any kind of temporal motor primitives with approximately no decrease of identification accuracy with respect to other standard techniques commonly used. With this algorithm, which is going to be distributed online as a freeware toolbox, we aim to provide a large research community in the field of motor control with an easy tool for the identification of motor primitives that avoid the confusion and inhomogeneity that the use of too many different techniques may imply.

The acquisition of hidden models in sensorimotor learning

Devika Narain[1], Pascal Mamassian[2], Eli Brenner[1], Jeroen B.J. Smeets[1], Robert J. van Beers[1]

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The framework known as Bayesian model selection has been used to explain rapid generalization and classification abilities during language acquisition in humans (Kemp & Tenenbaum 2008; Tenenbaum, Griffiths, Kemp, Goodman 2011; Griffiths, Chater, Kemp, Perfors, & Tenenbaum 2011). It has also been used to model learning behavior while performing complex visuo-motor tasks (Braun, Waldert, Aertsen, Wolpert & Mehring 2010; Genewein & Braun 2012). We extend this line of inquiry to ask how humans discover hidden dependencies among variables in sensorimotor environments over time. We first use a visuo-motor interception task to empirically establish that it is possible for humans to learn hidden models of varying complexity. Participants perform an experiment in which there is a hidden relationship between the value of an observed variable (location of a visual cue) and the required value of the response variable (interception time to a target). This relationship between the location and the time of a target represents models of different complexities (constant, linear, quadratic) that suddenly switch over the course of the experiment. Given the data, we infer which model was being used to generate the responses at different stages of the experiment using a method that controls for the different number of parameters in each model. We derive complete analytical solutions specific to each model using the principles of Bayesian model selection to obtain the posterior probability of each model given the data. We find that participants were able to correctly detect whether the hidden relationship in the stimuli followed a constant, linear or quadratic model. When the model that was used to generate the stimuli changed, participants were able to follow the change. Thus, participants constantly monitored the world relationship between the location and the time of a visual event. Further, they exhibited a preference for the simplest model that adequately explained the observed data. This provides support for the theory that human learning is model-based and consistent with theoretical principles such as Occam's razor.

Task-level brain-machine interfaces

Vikash Kumar[1], Yuval Tassa[1], Emo Todorov[1]

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Brain-machine interfaces (BMIs) have attracted a lot of attention, partly because of their promise to restore lost motor function, and partly because of the underlying scientific interest in decoding motor commands from brain activity. The accuracy of such decoding however is rarely sufficient. This is especially problematic for BMIs aiming to control prosthetic devices with many degrees of freedom. If BMIs are to achieve wide-spread use, they will likely have to be non-invasive and be able to accomplish the desired functional task almost all the time. We do not see how decoding of low-level motor commands will get us there anytime soon. At the same time, such decoding is not really necessary from an engineering perspective. The critical information that the BMI must provide is what task the user wants to perform and when. The details of how the task should be performed can be left to an automatic controller. In fact BMI researchers sometimes use automatic control in their demos to supplement decoding, however they tend to see this as a deficiency to be overcome later, while we see it as a feature to be exploited and fully developed. In this talk we will describe a prototype BMI system that uses eye tracking and speech recognition to obtain task specifications from a user, and then performs the specified tasks in a 3D virtual environment using automatic control. Suppose the user wants to make his prosthetic arm move an object on a table. All he has to do is say "move this here". When saying "this" it is natural to look at the object of interest. When saying "here" it is natural to look at the desired new location of the object. The system includes an eye tracker and a microphone, as well as off-the-shelf speech recognition software, allowing it to "decode" the task-level information without analyzing brain activity. Once the task specification is available, the rest is done by automatic control. Here we leverage our expertise in optimal control, in particular real-time trajectory optimization that can plan and execute movements for a dexterous robotic hand. Our controller can make the hand grasp, re-orient and place objects at specified locations while at the same time avoiding obstacles. The task can be modified by the user at any time. Since planning is done online, the system can responds to changes in user intent as well as unexpected disturbances instantaneously. Our existing system is still a prototype and more work remains to be done both on the decoding and on the control aspects, but its potential to help disabled people is already clear.

Sensorimotor reward modulation during motion and observation used to implement an actor-critic brain machine interface

Brandi Marsh[1], Aditya Tarigoppula[1], Chen Chen[1], Joseph Francis[1]

[1]SUNY Downstate

The neural activity in the primary motor cortex (M1) has been shown to encode movement kinematics and dynamics. For the first time, we present electrophysiological evidence that the firing rates of neurons in both M1 and S1 bilateral cortices of macaque monkeys modulate in response to differential reward expectations (reward modulation). Approximately 50% of the neural population fired higher for rewarding trials whereas ~25% fired higher for non-rewarding trials. Reward modulation was observed not only during active center out reaching tasks but also when the subject passively watched the computer cursor move towards the rewarding and non-rewarding targets. Furthermore, cross level coupling between local field potentials (LFP) and single unit spikes was observed to be stronger for rewarding trials than for non-rewarding trials. This suggests a higher dependence between the spike activity at the unit level and the oscillatory activity of the local network when expecting a reward. Finally, we were able to apply this knowledge to construct an actor-critic brain machine interface (AC-BMI) which is a critical step towards a completely unsupervised BMI. The neural activity in M1 was mapped to desired movements by the decoder (actor) and the corresponding reward signal extracted from the same neural ensemble was utilized as the evaluative signal (critic) of the performed action.

Session 11, Panel IV

Friday, April 19
10:45 – 13:00

What have we learned from a century of studying primary motor cortex?

Mohsen Omrani[1], Stephen H. Scott[1], Paul Cheney[2], Mark Churchland[3], Daniel Moran[4], Nicho Hatsopoulos5

[1]Queen's University, [2]University of Kansas Medical Center, [3]Columbia University, [4]Washington University in St. Louis, 5University of Chicago

It is more than 100 years passed since Hitzig and Fritsch discovered that electrical stimulation of primary motor cortex evokes peripheral movement. Many other physiologists, from Jackson and Ferrier to Penfield, pursued these findings in the hope to understand the mechanistic circuitry of movement. Modern electrophysiological techniques helped discover how different movement parameters covary with cortical activity, yet no consensus still exists on how the primary motor cortex contributes to the control of movement. The discussion has been swinging between theories suggesting a high level role (movement kinematics) for motor cortical areas to a low level role (movement dynamics). In addition, the extent to which feedforward motor plans interact with sensory feedback from the periphery is a matter of debate. As a graduate student interested in the physiology of motor control, I found these seemingly conflicting conclusions based on almost identical paradigms, quite confusing. I found it almost impossible to get a grasp of the nature of these conflicts without digging into the history of this line of research and reviewing evidence in favour of each theory. For that purpose I have invited 6 experts of the field, each with their unique approach and view to this problem, to discuss why they believe what they believe. This perspective session aims to provide a short historical overview of the debate and a grand debate on critical findings supporting each view. I would like to propose a full session (135 minutes) for this topic so we have enough time dedicated to an engaging discussion. I will give a short historical overview of the discussion (15 minutes), starting from early days of motor control and quickly introducing the concepts to be discussed further (Control of dynamics Vs. Kinematics & the role of feedforward Vs. feedback information). The session will then continue with each presenter, discussing how their line of research has helped decipher this mystery and why they favour their own view. Each presenter will provide a short talk (10 minutes), focusing on the canonical evidence supporting their view. The goal is to provide a bigger picture rather than presenting lots of data. To form a common ground for comparison across all presentations, the presenters are asked to at least cover four of my major questions in their presentation (refer to supplemental section). The second half of the session (60 minutes) is fully dedicated to discussion among the panel. I will ask each presenter to provide alternative explanations to the topics covered in the first part. However, given the diversity of the topics and to keep the discussions organized, I will ask each presenter to express their views on 3 specific questions (10-15 minutes each) which captures the essence of the discussion. The floor will also be open to audience contribution and the last 20 minutes is dedicated to audience questions to the panel. The hope is to provide future motor physiologists with a bigger picture of the debate which has been going on for more than 40 years. To evaluate whether this approach was successful and keep the audience engaged, we will have short anonymous questionnaires filled before and after the session. This aims to see whether this type of session has changed anybody's view on how motor cortex works. Please refer to the supplemental section for the list of participants and the view each presenter will bring forward in this discussion.

Session 13, Panel V

Saturday, April 20
08:00 – 10:15

What can we learn from rapid online corrections about the planning and control of reaching movements?

Leonie Oostwood Wijdenes[1], David Franklin[2], John Kalaska[3], Joseph Nashed[4], Alexandra Reichenbach5

[1]VU University Amsterdam [2]University of Cambridge, [3]University of Montreal, [4]Queen's University, 5University College London

People are able to correct their ongoing movements at very short latencies in response to perturbations of either the environment or their own arm. These rapid corrections are not standardized reflexes, but show a remarkable level of sophistication that requires extensive knowledge about the current state of the actor and its surroundings. In this session we will demonstrate the refinement, but also the limitations, of rapid online corrections. We will present models to interpret the use of visual information for corrections and to interpret how perturbations are attributed to the agent or to the environment, and we discuss whether online corrections are controlled by the same neural circuits as movement planning is. Joseph Nashed will demonstrate the refinement of online movement corrections in response to a mechanical perturbation. During voluntary movement, the motor system must consider various environmental factors, including the shape of the goal and/or the possible presence of intervening obstacles. He will show that mechanical perturbations engage rapid responses (via the transcortical pathway) that rival the sophistication of voluntary behaviour. Specifically, the nature of these corrective responses reflects complex issues (where and how to reach) related to properties of the goal, and obstacles in the environment (how to avoid them). David Franklin will discuss how rapid responses to visual motion can be used to investigate the control of reaching. The classical view on feedback control is that the brain calculates a difference vector between the target and hand positions which is then passed to the motor system to produce any required correction. Through examining the rapid responses to combinations of visual motion of the hand and target this intuitive theory can be directly tested due to its strong predictions. The results argue against the difference vector model and suggest instead that hand and target motion elicit partially independent responses that are integrated in later stages of the sensorimotor system. Alexandra Reichenbach will present how agency assignment processes visual information for motor control. The speed and specificity with which we react to movement relevant visual changes suggests that the visuomotor system 'knows' at each instant in time, which visual stimulus represents the body parts. Her experiments suggest that an attention-independent mechanism, agency assignment, links the motor plan of a body effector to its visual consequences. This mechanism outperforms visual perception in a complex scene, and renders the linking resistant to interference from distracting visual objects. The movement goal, in contrast, is processed by visual attention and susceptible to interference. John Kalaska will present evidence that the neural circuits implicated in sensorimotor transformations during the initial planning of reaching movements and during rapid online corrections for target jumps are at least partially independent, since subjects adjust their movement planning after learning a visuomotor dissociation, but do not show a corresponding adaptation of the initial directionality of the online correction mechanism. Nevertheless, a modelling study indicates that the output signal of the online correction mechanism must pass through neural circuits ("internal models") that take into account the dynamics of the ongoing reaching movement to execute both planned movements and online corrections successfully.

Session 14, Individual Presentations IV

Saturday, April 20
10:45 – 12:45

Motor learning in human development reveals distinct mechanisms of retention and savings

Kristin Musselman[1], Amy Bastian[1]

[1]Johns Hopkins School of Medicine

Motor learning, or the ability to improve movement with practice, comprises many behavioral and neural processes. Adaptation is one form of motor learning that occurs in response to predictable new sensorimotor demands. It uses error feedback from one movement to adjust feedforward control of the next. Adaptation of walking is known to be cerebellum dependent (Morton et al. 2006) and shows interesting properties when repeated across days. Specifically, adults show clear day-to-day retention of the adapted pattern as well as 'savings,' or faster adaptation after washout (i.e. de-adaptation; Malone et al. 2011). Here we asked whether day-to-day retention and savings of an adapted walking pattern occur in children aged 2 to 17. We have previously shown that adaptation is slower in children under age 11, though they learn the same amount as adults (Vasudevan et al. 2011). Here we hypothesized that retention and savings abilities might also develop well into childhood, particularly if they rely on the same neural substrates. We studied 81 children as they adapted their walking pattern on a split-belt treadmill, and returned the following day to test either retention (i.e. immediate recall of the adapted pattern) or savings (i.e. re-adaptation following washout). On Day 1, subjects adapted on the treadmill with one belt moving twice as fast as the other for 15 minutes. On Day 2 the children were randomly allocated into 1 of 2 groups. The 'retention' group walked for 15 minutes on the split-belt treadmill, as per the previous day. The 'savings' group first walked with the belts moving at the same speed for 15 minutes (washout period), followed by 15 minutes of split-belt walking. Spatial and temporal symmetry of the two legs were measured to characterize the learning. The extent of retention and savings were determined by studying Day 2 adaptation behavior. We were surprised to find clear differences in retention and savings across development. Children of all ages showed retention of the adapted walking pattern, suggesting that they can form context specific memories. This occurred regardless of their adaptation rate on day 1. In contrast, children aged 2-11 years did not show any savings. The washout period fully extinguished the motor memory, such that when they were exposed to split-belt walking on Day 2, their learning rate and initial errors were the same as Day 1. These findings suggest that retention and savings may differ in their underlying neural mechanisms and that these two abilities mature at different rates in humans. We speculate these findings may correspond with different maturation rates of specific brain regions--for example, primary sensory and motor cortex develop early (Gogtay et al. 2004) whereas many cerebellar regions can be delayed to age 11-15 (Tiemeier et al. 2010). Our results also suggest that compared with adults, the therapeutic benefits of split-belt walking may take longer to be realized in young children. Supported by a Canadian Institutes of Health Research Fellowship and NIH HD048741

Mechanisms of motor learning: adaptation vs. skil

Sebastian Telgen[1], Darius Parvin[1], Jörn Diedrichsen[1]

[1]University College London

Adaptation and skill learning are still predominantly differentiated by the type of task that is used to study them: Skill learning is assessed by sequential finger movements or movements with complex trajectories, whereas adaptation is probed by perturbing simple reaching movements using novel visuo-motor transformations or force fields. We argue that the differentiation should be based on mechanisms rather than tasks: Here, we define adaptation as a recalibration of an existing control policy, and skill learning as the establishment of a novel control policy that first needs longer planning and later can be recalled more efficiently. Our results show that it is possible to observe both mechanisms within a single reaching task by imposing different types of visuo-motor transformations. Skill learning and adaptation were studied using a reaching task, where the visual feedback was either mirrored around the midline or rotated by 40 degrees. Participants performed reaching movements in two separate sessions. During the first session participants made 576 reaching movements with manipulated visual feedback. The first and the second session were separated by a 12 or 24 hours delay. In the second session participants performed 864 movements with manipulated visual feedback. In both experiments the reaction times (RT) were enforced to be lower than 400ms. In the mirror-reversal learning task participants performed reaching movements towards targets located at 0, -20 or 20 degree relative to the mirror reversal axis. We observed a strong relationship between RT and movement direction, with shorter RTs leading to movements into the wrong direction. This speed-accuracy trade-off progressively shifted during learning, such that the same movement accuracy was achieved at shorter RTs. We argue that this is the signature of a new control policy slowly becoming automatized. We also directly observed an overlap of the old and new control policy within single trajectories by probing fast feedback responses to lateral displacements of the visual cursor. Even in the end of training, participants responded initially with a correction in the old direction, and only reversed their response further into the movement. During visual-rotation learning the visual feedback was rotated by 40 degree. There was no relationship between RT and initial reach direction, i.e. fast and slow trials were equally affected by learning in all phases. We interpret this as a recalibration of an existing and automatic control policy. Learning also differed in how behaviour changed in the break between the experimental sessions. For visual rotation, participants forgot part of the learned calibration overnight. For mirror-reversal, however, we found significant offline gains, i.e. spontaneous improvements in the speed-accuracy trade-off, both in the feedforward and the feedback command. These gains were most strongly expressed when the two sessions were separated by a night of sleep. Mirror reversal learning shows speed-accuracy trade-offs, automatization and offline gains, and therefore shares important features with many other skill learning tasks. In contrast, visual rotation learning appears to be subserved by a different learning mechanism. We therefore propose that the relationship between processing time and accuracy - and its evolution with learning - can serve as the defining criterion to distinguish between skill learning and adaptation.

Role assignment in human-human motor interaction

Alejandro Melendez-Calderon[1], Carlo Bagnato[2], Vicki Komisar[3], Etienne Burdet[2]

[1]Rehabilitation Institute of Chicago, [2]Imperial College London, [3]University of Toronto/Toronto Rehabilitation Institute

In everyday life we constantly and unconsciously synchronize our behavior with others. A typical example is the way we adapt our gestures and posture during face-to-face communication. Extensive studies have provided insights about the way we interact with each other through non-verbal communication; however physical interaction has been little studied. A major issue in analyzing how humans collaborate in a continuous mechanical interaction lies in the redundancy brought by the connection. Using a dedicated dual wrist flexion/extension robotic interface, we could systematically investigate how humans coordinate their wrist flexion/extension at both the interaction force and muscle levels. When subjects physically interact with a partner, distinct roles (e.g. dominant vs. non-dominant, executor-conductor, etc.) can be assigned to the interacting agents based on observed kinematic/dynamic patterns that emerge during the interaction. However, it is known from dynamical systems theory that patterns will emerge spontaneously as the result of large numbers of interacting components. Therefore, the significance of the different roles that have been found in previous studies is unclear. Are there any particular variables (e.g. hand dominance) that lead subjects to consistently converge to one role over the other? or, are those patterns just a reflection of a coupled dynamic system? To investigate how dyads of subjects coordinate their behavior during mechanical interaction, we carried out experiments in which subjects tracked a target using wrist flexion/extension. We tested three scenarios: 1) dyadic interaction (mechanical connection between the hands of two subjects); 2) bimanual interaction (mechanical connection between the hands of one subject) for reference of a similar redundant task controlled by a single subject; and 3) unimanual performance (no mechanical connection) as baseline. We analyzed the online interaction and coordination between individuals by looking at the evolution of forces and muscular activity. To test the robustness of observed interactive behaviors, visual feedback could be altered to encourage dyads to modify their interaction patterns. In this way we could systematically analyze why a dyad would favor a particular strategy over another. In contrast to previous studies suggesting that dominant behavior is linked to the person rather than to the interaction parameters, we found that role distribution among partners is not inherent in the individual, but rather emerges as a continuous adaptation between partners. Therefore, roles are dyad- and task-specific. In contrast to common expectation, role assignment did not depend on the relative strength of the interacting partners nor on hand dominance or previous bimanual task experience. We also observed a general trend for dyads to converge slowly to a baseline strategy. This baseline strategy was not the same on all dyads, suggesting that the solution for the task was not global but specific to each particular dyad. One interesting observation was the presence of multiple solutions. After encouraging specific interaction patterns between partners, dyads alternated between induced and baseline approaches. Analysis on the electromyography signals revealed a general tendency to synchronize muscle activation regardless of the resulting role in terms of interaction forces. The work was funded in part by the EU grant FP7-ICT-271724 HUMOUR.

Limitations of delayed feedback control suggest a forward update in state estimation following perturbations

Frederic Crevecoeur[1], Stephen Scott[1]

[1]Queen's University

Feedback control is essential for successful movements in the presence of external disturbances. Recent studies have shown that mechanical perturbations evoke very rapid (~50 ms), task-related responses. The underlying mechanism is still unclear and there is controversy regarding how sensory feedback may be processed to perform such rapid and accurate feedback responses. One hypothesis is that feedback control is based on low-level circuits that maintain the desired limb position through spinal reflex arcs. An alternate hypothesis is that feedback control is based on state estimation, which requires internal models and forward predictions of the present state of the limb based on delayed sensory signals. At the heart of this debate is the problem of time delays affecting sensory and motor transmission. To investigate the impact of feedback delays, we characterized the performance of two classes of control models with or without state estimation. The model performances were then compared to human motor responses to perturbations. Participants ($N = 9$) were seated and their arm was placed in a robotic exoskeleton allowing planar motion (KINARM, BKIN-Technologies). They were instructed to maintain postural control at a visual target. The shoulder joint was physically locked and perturbation pulses were applied at the elbow (±5 Nm for 50 ms with 10 ms build up/down). Participants had to return to the goal target (radius = 1 cm) in either 600 ms or 300 ms. The fastest return condition was extremely challenging and most corrective movements did not reach the target on time. However, subjects could reduce the maximum joint displacement ($t(8) > 4$, $P < 0.01$) with similar (+5 Nm, $t(8) = 1.19$, $P = 2.7$) or even reduced target overshoot across conditions (-5 Nm, $t(8) = 2.47$, $P < 0.05$). This occurred with little-to-no change in muscle co-contraction. We were not able to reproduce this aspect of motor behaviour with models that did not include state estimation: increasing the feedback gains lead to degraded control performance. Indeed, target overshoot and oscillations tended to increase with the feedback gains even when delays were as short as ~35 ms (25th percentile of measured responses onset from all muscle samples). Also, stability could not be guaranteed beyond uncertainties of the order of 10% of the magnitude of feedback gains, which makes these candidate mechanisms prone to unstable responses as soon as noise is injected into the model. In fact, all attempts to parallelhuman motor performance lead to unstable control processes. In contrast, the feedback controller coupled with a state estimator was able to simultaneously reduce the maximum joint displacement and the target overshoot as a result of an increase in the feedback gains. These results suggest that direct feedback control based on delayed sensory afferents cannot account for human motor performance. Instead, it seems likely that internal processing similar to a rapid update in state estimation guides feedback responses to perturbations.

Sensorimotor feedback based on task-relevant error robustly predicts temporal recruitment and multidirectional tuning of muscle synergies

Seyed Safavynia[1], Lena Ting[1]

[1]Emory University

Muscle synergies have been proposed as a library of motor actions that define the spatial patterns of muscle activity to achieve specific biomechanical goals. Although muscle synergies have been used to describe muscle activation patterns across a wide range of motor tasks, there have been no experimental studies that predict muscle activation patterns from measured muscle synergies. One obstacle to predicting muscle activation from muscle synergy patterns is that the neural mechanisms governing their recruitment across different movement contexts must be known. Here we hypothesized that muscle synergies for reactive balance during standing are recruited based on the task-level goal of maintaining the body in an upright, static posture. Our prior work demonstrated that the sensorimotor transformation determining temporal patterns of muscle synergies during reactive balance in the sagittal plane can be described by delayed feedback of center of mass (CoM) and not joint kinematics. Therefore we hypothesized that the task-level goal of maintaining the CoM above the base of support drives the recruitment of muscle synergies for multidirectional balance control. Our goal was to predict recruitment of muscle synergies in two experimental paradigms: 1) multidirectional uniphasic, ramp-and-hold support-surface perturbations in 12 horizontal plane directions (i.e. center-out perturbations) and 2) multidirectional biphasic perturbations that initially moved either forward or backward and then, before balance was recovered, perturbed the body in any of 12 horizontal plane directions (i.e. countermanding perturbations). In center-out perturbations, the temporal recruitment of 4-5 muscle synergies per subject was predicted across all perturbation directions based on the deviation of the CoM kinematics from the desired upright state 100 ms prior to the measured activity. Therefore, the recruitment of each muscle synergy across all perturbation directions in the horizontal plane was determined from a single set of feedback gains identified in the preferred perturbation direction. Muscle synergy recruitment across all directions was predicted using the projection of CoM kinematics along the preferred direction, producing cosine-like tuning curves. We then used countermanding perturbations to demonstrate that the recruitment of muscle synergies was determined by returning the body to the desired state and not the initial state of the CoM. By inducing destabilizing premovements in the forward and backward direction, we demonstrated that the recruitment of muscle synergies across directions were modified to reflect the changes in CoM kinematics from desired state versus the initial state at the time of the perturbation. Using the task-error, computed as the deviation of CoM kinematics from the desired vertical state, the changes in the muscle synergy tuning curves from strict cosine tuning functions was predicted. Therefore, sensorimotor feedback based on task-relevant error robustly predicts muscle synergy recruitment during standing balance control. Similar to locomotion, the neural mechanisms governing the temporal and spatial structure of motor outputs for balance appear to be distinct, allowing for the separation of abstract temporal motor goals from the underlying spatial implementation. This hierarchical organization may represent a common principle of motor control, allowing motor intentions to be transformed into motor actions.

Action and goal related decision variables modulate the competition between multiple potential targets

Vincent Enachescu[1], Vassilios Christopolous[2], Stefan Schaal[1]

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

We are continually faced with situations in which we must initiate an action before we are certain about exactly how to complete that action. In such situations, action-based decision theory posits that we prepare multiple potential plans that compete for action selection and use perceptual clues, movement meters and other pieces of information to bias the competition, until we select a single policy (Cisek, 2007). Imagine you are in cafe and reaching to finish your coffee, only to notice the server about to take away your mug; you could reach quickly and try to catch the server's hand, verbally scold them for rushing you, or simply reach for your friends' coffee and sneak a sip instead. Each choice requires a different set of movements and has a different probability of getting our reward. How does our brain proceed?   In previous work, when people were faced with multiple potential targets and only one is cued after reaching onset, they delayed to make a decision by aiming to an intermediate position between the targets, before correcting the movement in-flight to the cued target location. Manipulating a number of goal related variables, such as target location or predicted success were shown to bias this spatially averaged movement plan (Chapman, Goodale, et al. 2010). However, it is likely that more characteristics of the action itself, such as the amount of effort required or perceived difficulty of execution also bias the selection of actions. In this work, we use an adapted form of a simple pointing task used in the previous studies to investigate the role of both goal and action related variables in modulating the competition between potential actions. Subjects use a robotic manipulandum that allows for small range pointing motions; during each trial a number of pointing targets are presented to the subject, but only after the subject begins moving is the correct target highlighted. The robotic manipulandum is used to apply physical resistance while moving towards particular targets manipulating the cost of the associated action; while the location of the correct target is varied to manipulate the goal of the motion and its associated reward. We ran a series of experimental protocols designed to demonstrate the competition between pointing motions and analyzed how the spatially averaged trajectories shift in response to modulations of the action and goal related variables. Preliminary results showed that both goal and action related decisions variables modulate the motor plan competition. Particularly, we found that the initial reaching movements are biased towards the target with the highest expected outcome and the lowest reaching effort. To the best of our knowledge, this is the first study that shows that decision process in tasks with multiple potential targets involves both goal and action related decision variables.

Optimal strategies for throwing at high speeds

Madhusudhan Venkadesan[1], Akshay Srinivasan[2]

[1]National Centre for Biological Sciences, [2]University of Washington

Humans are unique among primates in their ability to throw at high speeds. Throwing involves the entire body, with a cascade of energy flow that starts at the legs and ends at the fingertips, leading to a fast, yet accurate throw. Here we use numerical optimal control and find that the optimum corresponds to a baseball pitcher. This optimal strategy uses torques at the hip, elastic energy storage at the shoulder, and kinetic energy transfer across multiple segments, resembling an elastically loaded whip. Past theoretical studies using optimal control restrict themselves solely to the arm. These use either 2D models, or fully actuated (one motor per joint) 3D models that fail to converge in the absence of `regularizing' cost and constraint terms like torque-squared, hand location at ball release and so on. Such regularizing terms are unrelated to the goal and used only to circumvent numerical difficulties. Experiments however suggest two competing theories, namely, elastic energy storage at the shoulder versus kinetic energy transfer across segments (like a slender whip). We build a whole body 3D model with one joint at the hip (rotation about the torso's long axis), two at the shoulder (ad-abduction and humeral torsion, in that order) and one at the elbow. We consider two variants, [A] with one motor at the hip and linear torsional springs at every other joint, or [B] motors at every joint but for a spring at humeral torsion. We first consider [A], and find hip torque history (scalar function of time), joint stiffnesses (3 scalars), spring neutral angles (3 scalars), and throw duration (1 scalar) to maximize release speed along a desired direction ('forward'). We constrain release angle (< 5 deg cone), joint range of motion, maximal hip torque (based on Alexander 1991), joint stiffness, and duration of the throw. We find three local maxima with bang-bang solutions for hip torque. We only consider those optima that do not "ride" the inequality constraints, i.e. lie on the interior of the inequality constraints. The fastest throw resembles a baseball pitch (33m/s) that uses elastic energy storage in the shoulder's humeral torsional spring, and a kinetic energy cascade along the arm's segments. The other two qualitatively similar throws rely on elastic energy storage at the elbow, and the kinetic energy cascade across segments. All three strategies exhibit extreme sensitivity of throwing accuracy to the release timing

(~4ms), comparable to estimates for humans (2-7ms, Calvin 1983). The nearly fully actuated model (three motors) is identical in all respects to the one motor model but for higher throwing speeds (41m/s). Our work this explains the strategy used by humans for high speed throwing, but does not address accuracy at those speeds. References: 1. RM Alexander. Journal of Theoretical Biology, 150(3):349-372 (1991). 2. WH Calvin. Journal of Theoretical Biology, 104(1):121-135 (1983).

Session 16, Keynote Address

Saturday, April 20
15:00 – 17:00

Sifting circuits for motor control

Thomas M Jessell[1]

[1]HHMI, Kavli University for Brain Science, Departments of Neuroscience, Biochemistry and Molecular Biophysics, Columbia University, New York, NY

This talk will examine two aspects of the organization of spinal circuits devoted to the control of limb movement – the logic of circuit assembly, and the link between circuit wiring and motor behavior. The application of molecular genetic methods to problems of neuronal diversity and connectivity has begun to emphasize the importance of neuronal settling position as an adjunct to cell recognition in driving the assembly of motor microcircuits. Through this analysis it has become evident that the detailed wiring of local motor circuits differs systematically, as a function of limb muscle position and the biomechanical demands of individual joints. Molecular appreciation of the vast diversity of spinal motor neuron and interneuron subtypes has also permitted more precise ways of perturbing, genetically, the function of individual spinal neuronal subsets and examining the consequences of such manipulations for motor behavior. Examples of the way in which this general approach can be applied to questions of local inhibitory control, and the internal representation of motor output, will be discussed.

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Notes

Poster Session 1 | By Author Name

All posters will be on display in Ballroom B & C
Wednesday April 17: 08:00 – 17:15 & Thursday April 18: 08:00 – 17:30

Themes

- A Adaptation & Plasticity in Motor Control
- B Control of Eye & Head Movement
- C Disorders of Motor Control
- D Fundamentals of Motor Control
- E Integrative Control of Movement
- F Poster Cluster (Churchland)

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

Author	Session	Theme	Board	*Poster No.
Abe, M	1	G	62	1-G-62
Ahmed, A	1	G	59	1-G-59
Albines, D	1	D	33	1-D-33
Allen, J	1	C	18	1-C-18
Barela, A	1	F	53	1-F-53
Barela, J	1	F	55	1-F-55
Bertucco, M	1	G	65	1-G-65
Bongers, R	1	A	3	1-A-3
Brennan, A	1	D	43	1-D-43
Brittain, J	1	C	24	1-C-24
Cagnan, H	1	C	26	1-C-26
Christou, E	1	A	7	1-A-7
Churchland, M	1	H	67	1-H-67
Chvatal, S	1	C	25	1-C-25
David, F	1	B	15	1-B-15
Distler, C	1	E	49	1-E-49
Drummond, N	1	D	42	1-D-42
Franklin, S	1	D	37	1-D-37
Genna, C	1	C	27	1-C-27
Goble, D	1	D	34	1-D-34
Grent-'t-Jong, T	1	D	30	1-D-30
Hadjiosif, A	1	G	58	1-G-58
Hawkins, K	1	C	20	1-C-20
hayashi, T	1	D	40	1-D-40
Howard, I	1	D	36	1-D-36
Kagerer, F	1	C	19	1-C-19
Kassavetis, P	1	D	39	1-D-39
Kimura, T	1	D	41	1-D-41
Laczko, J	1	A	2	1-A-2
Lam, E	1	G	60	1-G-60
Lan, N	1	C	17	1-C-17
Lappe, M	1	B	14	1-B-14
Little, S	1	C	28	1-C-28
Makowski, N	1	C	23	1-C-23
Marlinski, V	1	D	31	1-D-31
Marneweck, M	1	C	29	1-C-29
Masterson, J	1	A	10	1-A-10
McDonnall, D	1	G	66	1-G-66
McGregor, H	1	A	6	1-A-6
McGregor, K	1	D	35	1-D-35
Mirabella, G	1	D	32	1-D-32
Mirbagheri, M	1	C	22	1-C-22
Morehead, R	1	A	11	1-A-11
Nasir, S	1	A	5	1-A-5
Neely, K	1	C	16	1-C-16
Nisky, I	1	G	63	1-G-63
Niu, M	1	D	44	1-D-44
Novick, I	1	A	12	1-A-12
O'Brien, M	1	G	64	1-G-64
Oza, C	1	A	8	1-A-8
Phillips, C	1	E	51	1-E-51
Randerath, J	1	D	38	1-D-38
Rotella, M	1	A	9	1-A-9
Schwarz, D	1	F	57	1-F-57
Seely, J	1	H	68	1-H-68
Smeets, J	1	A	1	1-A-1
Snyder, K	1	F	54	1-F-54
Stewart, J	1	D	45	1-D-45
Sussillo, D	1	H	69	1-H-69
Tagliabue, M	1	E	48	1-E-48
Takiyama, K	1	G	61	1-G-61
Thura, D	1	E	50	1-E-50
Tunik, E	1	D	47	1-D-47
VanOpstal, J	1	B	13	1-B-13
Vazquez, A	1	A	4	1-A-4
White, O	1	E	52	1-E-52
Wolpe, N	1	D	46	1-D-46
YeonSun, S	1	F	56	1-F-56
Zangemeister, W	1	C	21	1-C-21

Poster Session 2 | By Author Name

All posters will be on display in Ballroom B & C
Friday April 19: 08:00 – 15:00 & Saturday April 20: 08:00 – 17:00

Themes

A Adaptation & Plasticity in Motor Control
B Control of Eye & Head Movement
C Disorders of Motor Control
D Fundamentals of Motor Control
E Integrative Control of Movement

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

Author	Session	Theme	Board	*Poster No.
Aman, J	2	C	24	2-C-24
Anderson, J	2	C	21	2-C-21
Bensmaia, S	2	D	42	2-D-42
Best, M	2	D	39	2-D-39
Bhanpuri, N	2	C	22	2-C-22
Bonaiuto, J	2	G	62	2-G-62
Caggiano, V	2	D	34	2-D-34
Carter, M	2	D	29	2-D-29
Chin-Cottongim, L	2	B	13	2-B-13
Christopoulos, V	2	G	61	2-G-61
Cluff, T	2	A	4	2-A-4
Coe, B	2	G	58	2-G-58
Dunning, A	2	D	37	2-D-37
Durocher, S	2	A	6	2-A-6
Ego, C	2	B	15	2-B-15
Faisal, A	2	D	41	2-D-41
Franquemont, L	2	D	27	2-D-27
Frost, S	2	A	5	2-A-5
Hasson, C	2	G	57	2-G-57
Hirata, Y	2	A	3	2-A-3
Jamali, M	2	E	45	2-E-45
Johnson, L	2	G	60	2-G-60
Kasuga, S	2	A	11	2-A-11
Kawai, R	2	D	35	2-D-35
Kline, J	2	D	38	2-D-38
Knikou, M	2	A	1	2-A-1
Kristeva, R	2	A	9	2-A-9
Kukke, S	2	C	17	2-C-17
Kutch, J	2	C	20	2-C-20
Lametti, D	2	A	8	2-A-8
Leonard, J	2	F	52	2-F-52
Little, C	2	F	50	2-F-50
Lodha, N	2	E	46	2-E-46
Lunardini, F	2	C	26	2-C-26
Miall, C	2	C	19	2-C-19
Miller, D	2	C	18	2-C-18
Miller, L	2	E	48	2-E-48
Miyamoto, Y	2	G	55	2-G-55
Murray, A	2	D	43	2-D-43
Nasseroleslami, B	2	G	56	2-G-56
Nessler, J	2	F	49	2-F-49
Nguyen, C	2	E	47	2-E-47
Nugent, M	2	D	32	2-D-32
Oliveira, M	2	C	25	2-C-25
OrbanDeXivry, J	2	A	10	2-A-10
Oya, T	2	D	33	2-D-33
Panouilleres, M	2	A	12	2-A-12
Philip, B	2	A	7	2-A-7
Phillips, J	2	B	16	2-B-16
Ramakrishnan, A	2	D	30	2-D-30
Saglam, M	2	B	14	2-B-14
Sawers, A	2	A	2	2-A-2
Sayegh, P	2	D	28	2-D-28
Schaal, S	2	G	54	2-G-54
Shinya, M	2	F	53	2-F-53
Srivastava, S	2	F	51	2-F-51
Stevens, J	2	C	23	2-C-23
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Vaidya, M	2	G	63	2-G-63
Vargas-Irwin, C	2	D	36	2-D-36
Yarossi, M	2	D	40	2-D-40
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Poster Sessions | Authors, Titles and Affiliations

Session 1 **Posters are listed by theme.**

A - Adaptation & Plasticity in Motor Control

1-A-1 Incomplete adaptation as a combination of learning and forgetting

Jereon Smeets[1], Katinka van der Kooij[1], Robert van Beers[1], Eli Brenner[1]

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1-A-2 Speed and crank resistance affects coactivation of knee muscles during cycling movements

Peter Katona[1], Tamas Pilissy[2], Jozsef Laczko[2]

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1-A-3 Changes in kinematics when learning to use a pair of pliers with different transformations

Raoul Bongers[1], Laura Golenia[1], Leonoor Mouton[1], Marina Schoemaker[1]

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1-A-4 Cerebellar damage degrades motor and perceptual aftereffects following walking adaptation

Alejandro Vazquez[1], Stefanie Busgang[2], Amy Bastian[2]

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1-A-5 Neural synchrony in speech motor learning

Ranit Sengupta[1], Sazzad Nasir[1]

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1-A-6 Motor learning by observing: A resting-state fMRI study

Heather McGregor[1], Paul Gribble[1]

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1-A-7 Reduction of movement variability with practice in older adults is associated with greater motor unit modulation from 13-30 Hz

Evangelos Christou[1], Tanya Onushko[1]

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1-A-8 Changes in representation of trunk muscles in the motor cortex after complete thoracic spinal cord injury and rehabilitation training

Chintan Oza[1], Simon Giszter[1]

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1-A-9 Transfer of isometric motor learning depends on the mapping of force input to cursor movement

Michele Rotella[1], Margaret Koehler[1], Ilana Nisky[1], Amy Bastian[2], Allison Okamura[1]

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1-A-10 The role of emotion, vision and touch in movement learning

Jeanne Masterson[1]

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1-A-11 A target is not necessary for visuomotor adaptation

Ryan Morehead[1], Richard Ivry[1]

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1-A-12 Neuronal correlates of prediction in the motor cortex of primates

Itai Novick[1], Eilon Vaadia[1]

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B - Control of Eye & Head Movement

1-B-13 Neural encoding of head-free gaze shifts in monkey superior colliculus

John van Opstal[1]

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1-B-14 Adaptation of micro-saccades reveals oculomotor control at the limits of precision

Katharina Havermann[1], Claudia Cherici[2], Michele Rucci[2], Markus Lappe[1]

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1-B-15 Foveal and peripheral vision result in similar pointing accuracy and variability during memory-guided pointing

Fabian David[1], Ruth Tangonan[1], Lisa Chin-Cottongim[1], Daniel Corcos[1]

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C - Disorders of Motor Control

1-C-16 Specific brain networks relate to tremulous (3-8 Hz) and slow (0-3 Hz) oscillations in force in essential tremor

Kristina Neely[2], Ajay Kurani[1], Priyank Shukla[2], Aparna Wagle Shukla[2], Jennifer Goldman[3], Daniel Corcos[2], Michael Okun[2], David Vaillancourt[2]

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1-C-17 Kinematic and EMG characteristics during reach and posture tasks in parkinsonian patients

Ning Lan[1], Xin He[1], Manzhao Hao[1], Ming Wei[1], Qin Xiao[1]

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1-C-18 Changes in motor module organization affect biomechanical output during post-stroke hemiparetic walking

Jessica Allen[1], Steven Kautz[2], Richard Neptune[1]

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1-C-19 Non-speech movements in developmental stuttering: what do they tell us?

Florian Kagerer[1], Soo-Eun Chang[1]

[1]Michigan State University

1-C-20 Measuring cognitive-motor integration in preclinical Alzheimer's disease: A discriminant analysis and investigation of neural correlates

Kara Hawkins[1], Lauren Sergio[1]

[1]York University

1-C-21 How is driving ability in patients with Parkinson´s disease (PD) affected by subthalamic nucleus deep brain stimulation (DBS)?

Prof Wolfgang Zangemeister[1] Lea Maintz[1], Thomas Wriedt[1], Carsten Buhmann[1]

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1-C-22 SCI-induced spasticity

Mehdi Miragheri[1], Xun Niu[1], Matt Kindig[2], Deborah Varoqui[1], Petra Conaway[2]

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1-C-23 Exploring the feasibility of a post-stroke neuroprosthesis: Can FES produce useful reach and hand opening during limited voluntary effort and can assistive forces be controlled using residual movements?

Nathaniel Makowski[1], Jayme Knutson[2], John Chae[2], Patrick Crago[1]

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1-C-24 Tremor suppression by rhythmic transcranial current stimulation

John-Stuart Brittain[1], Penny Probert-Smith[1], Tipu Aziz[1], Peter Brown[1]

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1-C-25 Absence of postural muscle synergies for balance following spinal cord transection in cats

Stacie Chvatal[1], Jane Macpherson[2], Gelsy Torres-Oviedo[3], Lena Ting[1]

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1-C-26 Tremor control using low frequency deep brain stimulation

Hayriye Cagnan[1], Carole Joint[2], Beth Forrow[2], Alex Green[1], Tipu Aziz[1], Peter Brown[1]

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1-C-27 Time dependent correlation between muscle synergies patterns and motor impairment in stroke survivors: a preliminary study

Clara Genna[1], Stefano Silvoni[1], Michela Agostini[1], Andrea Turolla[1]

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1-C-28 Responsive deep brain stimulation controlled by beta oscillations is effective for the treatment of Parkinsons disease in humans

Simon Little[1], Peter Brown[1], Ludvic Zvinco[2], Tipu Aziz[1], Alek Pogosyan[1], Alex Green[1]

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1-C-29 Discriminating facial expressions of emotion in Parkinson's disease

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D – Fundamentals of Motor Control

1-D-30 Oscillatory dynamics of response competition in human sensorimotor cortex

Tineke Grent-'t-Jong[1], Robert Oostenveld[1], Ole Jensen[1], Pieter Medendorp[1], Peter Praamstra[1]

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1-D-31 Reticular nucleus of the thalamus differently gates signals coding locomotor movements of proximal and distal parts of the forelimb

Vladimir Marlinski[1], Irina Beloozerova[1]

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1-D-32 Neural signatures of reaching movement inhibition in lateral frontal areas

Giovanni Mirabella[1], Silvia Spadacenta[1], Luigi Pavone[2], Pierpaolo Quarato[2], Vincenzo Esposito[2], Antonio Sparano[2], Fabio Sebastiano[2], Giancarlo Di Gennaro[2], Roberta Morace[2], Gianpaolo Cantore[2], Maurizio Mattia[3]

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1-D-33 Sex and experience-related difference in bimanual coordination development

David Albines[1]

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1-D-34 Agonist/antagonist tendon vibration at the elbow induces proprioceptive bias - but does not elicit noise

Tomas Gonzales[1], Daniel Goble[1]

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1-D-35 Unimanual dexterity performance in relation to measures of transcallosal inhibition

Keith McGregor[1], Atchar Sudhyadhom[2], Joe Nocera[3], Carolynn Patten[4], Bruce Crosson[3], Andrew Butler[5]

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1-D-36 Future movement affects the encoding of motor memory

Ian Howard[1], Daniel Wolpert[2], David Franklin[2]

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1-D-37 Visuomotor feedback gains adapt to environmental dynamics

Sae Franklin[1], Daniel Wolpert[1], David Franklin[1]

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1-D-38 Two routes to action selection - an fMRI repetition suppression study

Jennifer Randerath[1], Kenneth Valyear[1], Benjamin Philip[1], Scott Frey[1]

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1-D-39 Motor surround inhibition in human hand

Panagiotis Kassavetis[1], Mehdi Van Den Bos[1], Anna Sadnicka[1], Tabish Saifee[1], Isabel Pareés[1], John Rothwell[1], Mark Edwards[1]

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1-D-40 Fast corrective responses to perturbations applied during reaching reflect estimated limb state: Evidence for optimal feedback control in the motor system

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

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1-D-41 A novel robotized TMS system enabling the stimulation of multiple adjacent points of the human brain

Takahiro Kimura[1], Ichiro Hidaka[1], Hiroshi Kadota[2], Masaya Hirashima[1], Daichi Nozaki[1]

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1-D-42 Bihemispheric tDCS over motor cortex does not influence free choice

Neil Drummond[1], Gabrielle Hayduk-Costa[1], Michael Carter[1], Anthony Carlsen[1]

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1-D-43 The identification of a rapidly-decaying, high-precision proprioceptive sensory memory & its effects on motor adaptation

Andrew Brennan[1], Howard Wu[1], Maurice Smith[1]

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1-D-44 Non-linear filtered electromyograph (EMG) from hand muscle can produce recognizable vowels in real-time

C. Minos Niu[2], John Houde[1], Terence Sanger[2]

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1-D-45 Two distinct patterns of brain activation during motor action selection in older adults

Jill C. Stewart[1], Xuan Tran[1], Steven C. Cramer[1]

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1-D-46 Seeing what you want to see: a Bayesian account

Noham Wolpe[1], Daniel Wolpert[1], James Rowe[1]

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1-D-47 Ventral premotor area and anterior intraparietal sulcus contributions for updating hand preshaping during perturbations of object shape

Eugene Tunik[1], Scott Grafton[2], Sergei Adamovich[3]

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E - Integrative Control of Movement

1-E-48 Inter-manual, but not intra-manual reaching tasks induce visual encoding of purely kinesthetic sensory information

Michele Tagliabue[1], Joeseph McIntyre[1]

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1-E-49 Direct projections from dorsal premotor cortex (F2) to the superior colliculus in macaques

Claudia Distler[1], Klaus-Peter Hoffmann[1]

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1-E-50 A common urgency/vigor signal governs speed-accuracy trade-offs in both decision-making and movement execution

David Thura[1], Jessica Trung[1], Paul Cisek[1]

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1-E-51 Postural responses to electrical stimulation of individual ampullary nerves in human subjects

Christopher Phillips[1], Christina DeFrancisci[1], Leo Ling[1], Kaibao Nie[1], Amy Nowack[1], James Phillips[1], Jay Rubinstein[1]

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1-E-52 Effect of motor imagery on pupil dilation

Olivier White[1], Robert French[1]

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F – Posture & Gait

1-F-53 The use of partial body weight support system on static and dynamic surfaces for children with cerebral palsy

Ana Barela[1], Melissa Celestino[1], Gabriela Gama[1], Meico Fugita[1], Paulo de Freitas[1], Jose Barela[1]

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1-F-54 Walking on uneven terrain elicits increased electrocortical network activity compared to flat terrain

Kristine Snyder[1], Daniel Ferris[1]

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1-F-55 Effects of manipulation of visual stimulus characteristics on postural control in dyslexic children

José Barela[1], Milena Razuk[1], Paulo de Freitas[1]

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1-F-56 Strychnine alters ankle flexor-extensor muscle activity pattern in chick embryos

Soo Yeon Sun[1], Nina Bradley[1]

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1-F-57 Methods for large-scale wireless recordings in unrestrained monkeys

David Schwarz[1], Mikhail Lebedev[1], Timothy Hanson[2], Miguel Nicolelis[1]

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G - Theoretical & Computational Motor Control

1-G-58 Motor personalities and motor moods in the retention of visuomotor adaptation

Alkis Hadjiosif[1], Biljana Petreska[1], Maurice Smith[1]

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1-G-59 Is there a reaching speed that minimizes metabolic cost?

Helen Huang[1], Alaa Ahmed[2]

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1-G-60 The impact of motion stimulus variability on the temporal dynamics of a target selection task

Edmund Lam[1], John Kalaska[1]

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1-G-61 Prospective error to determine motor learning: A step toward a unified model of motor learning

Ken Takiyama[1], Masaya Hirashima[2], Daichi Nozaki[2]

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1-G-62 Effects of motor optimization and social interaction on an interpersonal force matching task

Masaki Abe[1],Katsumi Watanabe[1]

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1-G-63 Sensorimotor performance in robot-assisted surgery

Ilana Nisky[1], Michael Hsieh[1], Allison Okamura[1]

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1-G-64 The influence of threat on movement control under risk

Megan O'Brien[1], Alaa Ahmed[1]

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1-G-65 A model to estimate the channel capacity in pointing movement using assistive communication devices in children with cerebral palsy

Matteo Bertucco[1], Ritika Singh[1], Terence Sanger[1]

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1-G-66 A stimulator/amplifier using hundreds of electrodes for neural motor control

Scott Hiatt[1], Christopher Smith[1], Daniel McDonnall[1], Shane Guillory[1]

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H – Poster Cluster (Churchland)

1-H-67 A large untuned signal in motor cortex predicts movement onset

Matthew Kaufman[1], Jeffrey Seely[2], Stephen Ryu[3], Krishna Shenoy[4], Mark Churchland[2]

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1-H-68 Quantifying representational and dynamical structure in visual and motor cortex responses

Jeffrey Seely[1], Matthew Kaufman[2], Adam Kohn[3], Matthew Smith[4], J Movshon[5], Nicholas Priebe[6], Stephen Lisberger[7] , Stephen Ryu[8], David Sussillo[8], Krishna Shenoy[8], Larry Abbott[1], John Cunningham[9], Mark Churchland[1]

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1-H-69 A recurrent neural network that produces EMG from rhythmic dynamics

David Sussillo[3], Mark Churchland[1], Matt Kaufman[2], Krishna Shenoy[3]

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Poster Sessions | Authors, Titles and Affiliations

Session 2 **Posters are listed by theme.**

A - Adaptation & Plasticity in Motor Control

2-A-1 Functional reorganization of spinal cord circuitry after locomotor training in human spinal cord injury

Chaithanya Mummidisetty[1], Andrew Smith[2], William Zev Rymer[1]

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2-A-2 Increased hip torque rather than step width is used to maintain medial-lateral locomotor stability during unpredictable challenges to balance control

Andrew Sawers[1]

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2-A-3 Cerebellar neuronal network model during adaptive robot control

Yutaka Hirata[1], Ruben Dario Pinzon Morales[1]

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2-A-4 Altered long-latency responses reveal paralleladaptation of feedforward and feedback control

Tyler Cluff[1], Stephen Scott[1]

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2-A-5 Reliability in the location of hindlimb motor representations in Fischer-344 Rats

Shawn Frost[1], Maria Iliakova[1], Caleb Dunham[1], Scott Barbay[1], Paul Arnold[1], Randolph Nudo[1]

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2-A-6 Evidence for independent control of the visuomotor mapping for the planning rapid online correction of reaching movements

Valeriya Gritsenko[1], John F. Kalaska[1]

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2-A-7 Learning to draw with the non-dominant hand

Benjamin Philip[1], Scott Frey[1]

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2-A-8 A brief period of reinforcement-based perceptual training causes long lasting changes in motor learning

Daniel Lametti[1], Sonia Krol[2], Douglas Shiller[3], David Ostry[2]

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2-A-9 Which Gaussian noise bandwidth best improves sensorimotor performance and is most pleasant?

Carlos Trenado[1], Areh Mikulic[1], Elias Manjarrez[2], Ignacio Mendez-Balbuena[1], Frank Huethe[1], Jürgen Schulte-Mönting[3], Marie-Claude Hepp-Reymond[4], Rumyana Kristeva[1]

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2-A-10 Reoptimization of motor behaviors

Jean-Jacques Orban de Xivry[1]

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2-A-11 Trial-by-trial error correction strategy during mirror-reversal transformation learning

Shoko Kasuga[1], Junichi Ushiba[1], Daichi Nozaki[2]

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2-A-12 Effect of transcranial direct current stimulation on motor learning and retention in young and elderly adults

Muriel Panouilleres[1], John-Stuart Brittain[1], Raed Joundi[1], Peter Brown[1], Ned Jenkinson[1]

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B - Control of Eye & Head Movement

2-B-13 The effects of unilateral vs. bilateral subthalamic nucleus deep brain stimulation on visually-guided saccades and anti-saccades

Lisa Chin-Cottongim[1], Fabian David[1], Howard Poizner[2], John Sweeney[3], David Vaillancourt[4], Leo Verhagen5, Daniel Corcos[1]

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2-B-14 Cerebellar and vestibular contributions to optimal gaze shifts

Murat Saglam[1], Stefan Glasauer[1], Nadine Lehnen[1]

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2-B-15 The development of the saccade-pursuit interaction: evidence for immaturity of cerebellar functions in children

Caroline Ego[1], Jean-Jacques Orban de Xivry[1], Marie-Cécile Nassogne[1], Demet Yüksel[1], Philippe Lefèvre[1]

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2-B-16 Eye movements resulting from canal specific electrical stimulation in human subjects

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

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C - Disorders of Motor Control

2-C-17 Reach-to-grasp kinematics in hemidystonic cerebral palsy

Sahana Kukke[1], Lindsey Curatalo[2], Ana Carolina de Campos[1], Laurie Ohlrich[1], Katharine Alter[1], Mark Hallett[1], Diane Damiano[1]

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2-C-18 Galvanic evoked vestibulospinal reflexes in the lower limbs of chronic hemiparetic stroke subjects

Derek Miller[1], Cliff Klein[2], Emily Case[2], William Rymer[1]

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2-C-19 The effects of deafferentation on reach, grasp and object manipulation

Chris Miall[1], Maria-Andreea Olariu[1], Imogen Dalziel[1]

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2-C-20 The neural representation of the pelvic region and its implications for localizing the source of chronic pelvic pain

Moheb Yani[1], Louise Cosand[1], Manku Rana[1], Daniel Kirages[1]

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2-C-21 Eye movements and postural stability in traumatic brain injury

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2-C-22 Evoked potentials from deep brain stimulation in childhood dystonia

Nasir Bhanpuri[1], Matteo Bertucco[1], Diana Ferman[1], Scott Young[2], Terrence Sanger[1]

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2-C-23 Assessing mu rhythm in spinal cord injury patients

Jennifer Stevens[1], Caitlin Duckett[1], Rebecca Avison[1], Juliet Blakeslee-Carter[1], Rachel Sillcox[1]

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2-C-24 Deep brain stimulation of the subthalamic nucleus improves haptic perception in Parkinson's disease

Joshua Aman[1], Aviva Abosch[1], Chia-Hao Lu[1], Maggie Bebler[1], Juergen Konczak[1]

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2-C-25 Finger independency and multi-finger force control in children with DCD

Marcio Oliveira[1]

[1]University of Maryland

2-C-26 Poor motor performance and motor learning in childhood dystonia: speed-accuracy and movement variability in complex daily-life activities

Francesca Lunardini[1], Nasir Bhanpuri[2], Matteo Bertucco[2], Claudia Casellato[3], Alessandra Pedrocchi[3], Dagmar Sternad[4], Terence Sanger[2]

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D - Fundamentals of Motor Control

2-D-27 Temporal sequencing of instruction cues changes movement related activity in primate primary motor and ventral premotor cortex

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

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2-D-28 Differences between the single cell activity of the rostral and caudal subregions of PMd during decoupled/complex complex visuomotor control

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

[1]York University

2-D-29 Startle neural activity is additive with normal cortical initiation-related activation

Michael Carter[1], Dana Maslovat[2], Neil Drummond[1], Michael Kennefick[1], Anthony Carlsen[1]

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2-D-30 Feedback effects in a spinal wipe reflex

Arun Ramakrishnan[1]

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2-D-31 Symbolic encoding of complex actions by movement primitives

Andreas Thomik[1], Aldo Faisal[1]

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2-D-32 Patterns of muscle activation in the high frequency bellydance shimmy

Marilee Nugent[1], Theodore Milner[1]

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2-D-33 Synaptic distribution patterns of rubromotoeuronal cells onto forelimb muscles for a whole-limb movement in the macaque monkey

Tomomichi Oya[1], Tomohiko Takei[1], Kazuhiko Seki[1]

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2-D-34 The organization and extent of GABA inhibitory interneuronal networks in the spinal cord

Vittorio Caggiano[1], Mriganka Sur[1], Emilio Bizzi[1]

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2-D-35 Dissociating the role of motor cortex in the acquisition and control of learned motor sequences

Risa Kawai[1], Bence Olveczky[1]

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2-D-36 Context-dependent changes in ventral premotor cortex grasping-related activity: effects of object orientation and multiple grip affordances

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

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2-D-37 The tuning of human motor response to uncertainty and risk in a dynamic environment task

Amber Dunning[1], Matteo Bertucco[1], Atiyeh ghoreysh[1], Terence Sanger[1]

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2-D-38 Effects of walking speed on intrastride electrocortical activity in humans

Julia Kline[1], Daniel Ferris[1]

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2-D-39 Response properties in ventral and dorsal premotor cortex during natural reach to grasp movements

Matthew Best[1], Kazutaka Takahashi[1], Noah Huh[1], Kevin Brown[1], Nicho Hatsopoulos[1]

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2-D-40 Increased motor output is associated with M1 motor map expansion during isometric finger contraction

Mathew Yarossi[1], Greg Ames[1], Eugene Tunik[1]

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2-D-41 Towards the human ethome

Andreas Thomik[1], Marie Tolkiehn[1], Ingrid Vella[1], Aldo Faisal[1]

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2-D-42 Proprioceptive representations of the hand in primary somatosensory cortex

Sliman Bensmaia[1], Gregg Tabot[1], Alexander Rajan[1], Nicholas Hatsopoulos[1]

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2-D-43 Sensory-motor organization of vestibulospinal circuits

Andrew Murray[1], Niccolò Zampieri[1], Thomas Jessell[1]

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E - Integrative Control of Movement

2-E-44 Interception of a ball falling on an inclined plane

Myrka Zago[1], Barbara La Scaleia[1], Francesco Lacquaniti[1]

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2-E-45 Strong positive correlations between variability and sensitivity promote homogeneous linear motion detection thresholds across a heterogeneous otolith afferent population

Mohsen Jamali[1], Jerome Carriot[1], Maurice Chacron[1], Kathleen Cullen[1]

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2-E-46 Differential modulation of inter-hemispheric interactions during maximal force production and submaximal force control tasks

Neha Lodha[1], William Triggs[1], Carolynn Patten[1]

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2-E-47 Fitts' Law relationships of single-muscle myocontrol with Bayesian-filtered surface EMG in healthy adults and children with dystonia

Cassie Nguyen[1], Adam Feinman[1], Matteo Bertucco[1], Terence Sanger[1]

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2-E-48 Intermediate EMG prediction from M1 discharge improves online cursor control performance

Christian Ethier[1], Jose Sanabria[1], Lee Miller[1]

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F – Posture & Gait

2-F-49 Varying body weight support in bipedal stepping rats: Changes in locomotor behavior are partially related to alterations in hindlimb posture

Jeff Nessler[1], Moustafa Moustafa[2], Jessica Duhon[1], Ryan Schmitt[1], Dalziel Soto[1]

[1]California State University, San Marcos, [2]California State Polytechnic University, Pomona

2-F-50 The role of attention in fall avoidance: Evaluation of dual task interference with postural and visual working memory tasks in young and older adults: Does capacity limitation influence postural responses?

Marjorie Woollacott[1]

[1]University of Oregon

2-F-51 Coordination of leg muscles related to footpath stabilization during over ground walking post-stroke

Shraddha Srivastava[1], Pei-Chun Kao[1], John Scholz[1]

[1]University of Delaware

2-F-52 The dynamics of online corrections determine the mode of posture and movement coordination

Julia Leonard[1], Alexander Stamenkovic[2], Sophie Bos[2], Paul Stapley[2]

[1]Université de Montréal, [2]University of Wollongong

2-F-53 Does postural adaptation to moving platform transfer across voluntary sway and arm raising tasks?

Masahiro Shinya[1], Daich Nozaki[1], Kimitaka Nakazawa[1]

[1]The University of Tokyo

G - Theoretical & Computational Motor Control

2-G-54 Using path integrals to learn neuromotor controls of reaching movements

Stefan Schaal[1], Vince Enachescu[1]

[1]University of Southern California

2-G-55 A modified random walk describes the low dimensional structure of motor variability in reaching trajectories

Yohsuke Miyamoto[1], Maurice Smith[1]

[1]Harvard University

2-G-56 Dynamic predictability in rhythmic object manipulation

Bahman Nasseroleslami[1], Christopher Hasson[1], Dagmar Sternad[1]

[1]Northeastern University

2-G-57 Error amplification improves performance by reducing motor noise

Christopher Hasson[2], Masaki Abe[1], Zhaoran Zhang[2], Dagmar Sternad[2]

[1]The University of Tokyo, [2]Northeastern University

2-G-58 A model of saccade control that emulates both healthy and clinical populations

Brian Coe[1], Thomas Trappenberg[2], Douglas Munoz[1]

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

2-G-59 Changes in reward landscape modulate motor learning

Michael Trent[1], Alaa Ahmed[1]

[1]University of Colorado, Boulder

2-G-60 Efficient codes for multi-modal pose regression

Leif Johnson[1], Joseph Cooper[1], Dana Ballard[1]

[1]University of Texas at Austin

2-G-61 An optimal control framework for studying action-based decision making

Vasileios Christopoulos[1], Paul Schrater[2], James Bonaiuto[1], Richard Andersen[1]

[1]California Institute of Technology, [2]University of Minnesota

2-G-62 Integration of dynamic neural fields and an optimal control framework for action-based decision making

James Bonaiuto[1], Vasileios Christopoulos[1], Richard Andersen[1]

[1]California Institute of Technology

2-G-63 "Causal" coordination between reaching and grasping related neural trajectories in primary motor cortex

Mukta Vaidya[1], Maryam Saleh[2], Kazutaka Takahashi[1], Konrad Kording[2], Nicholas Hatsopoulos[1]

[1]University of Chicago, [2]Northwestern University

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Sebastian Telgen	University College London	Jörn Diedrichsen
Sahana Kukke	National Institutes of Health	Diane Damiano
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Poster Author Index | By Author Name

All posters will be on display in Ballroom B & C

Poster Session 1: Wednesday April 17: 08:00 – 17:15
Thursday April 18: 08:00 – 17:30

Poster Session 2: Friday April 19: 08:00 – 15:00
Saturday April 20: 08:00 – 17:00

Posters in bold represent first author
The poster board numbers work in the following way:
Session – Theme – Board Number (E.g. 2-A-43)

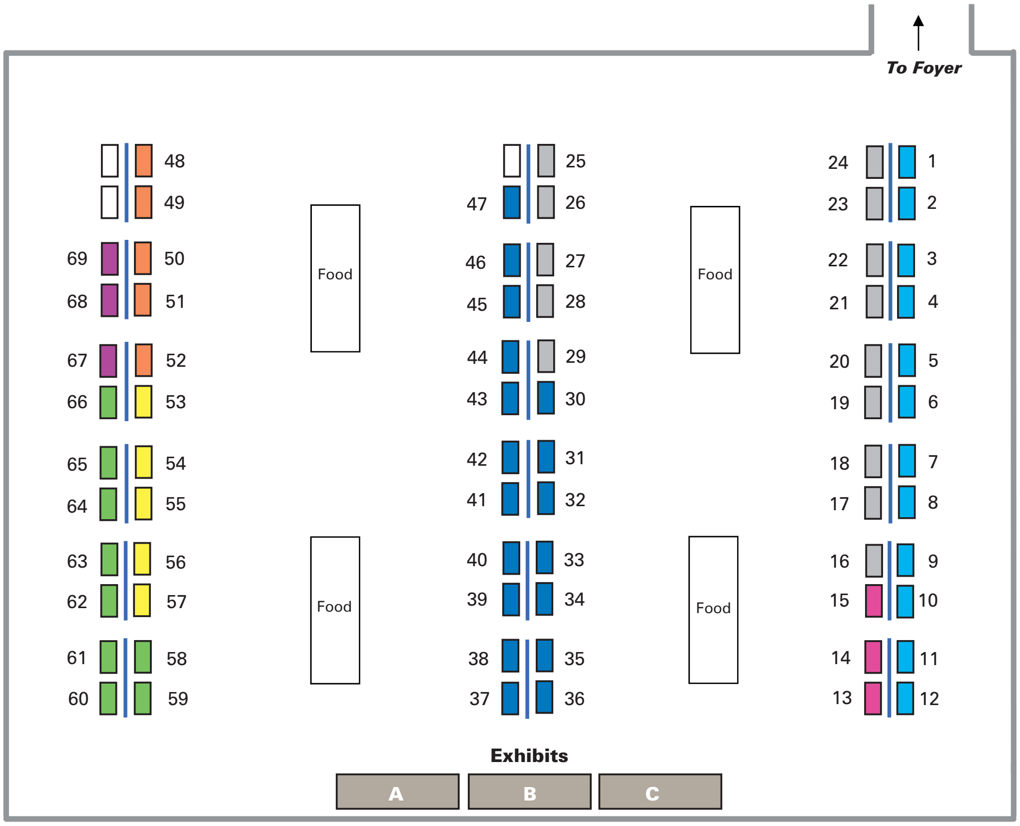
Themes

A	Adaptation & Plasticity in Motor Control
B	Control of Eye & Head Movement
C	Disorders of Motor Control
D	Fundamentals of Motor Control
E	Integrative Control of Movement
F	Poster Cluster (Churchland)

Poster Author Index | By Author Name

Poster Session Floor Plans

Ballroom B & C



Poster Layout

Session 1

Wednesday April 17
& Thursday April 18

🟦 A Adaptation & Plasticity in Motor Control

🟥 B Control of Eye & Head Movement

▨ C Disorders of Motor Control

🟦 D Fundamentals of Motor Control

🟧 E Integrative Control of Movement

🟨 F Posture & Gaitiaa

🟩 G Theoretical & Computational Motor Control

🟪 H Poster Cluster (Churchland)

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A Blackrock Microsystems
B Ripple
C Northern Digital Inc.

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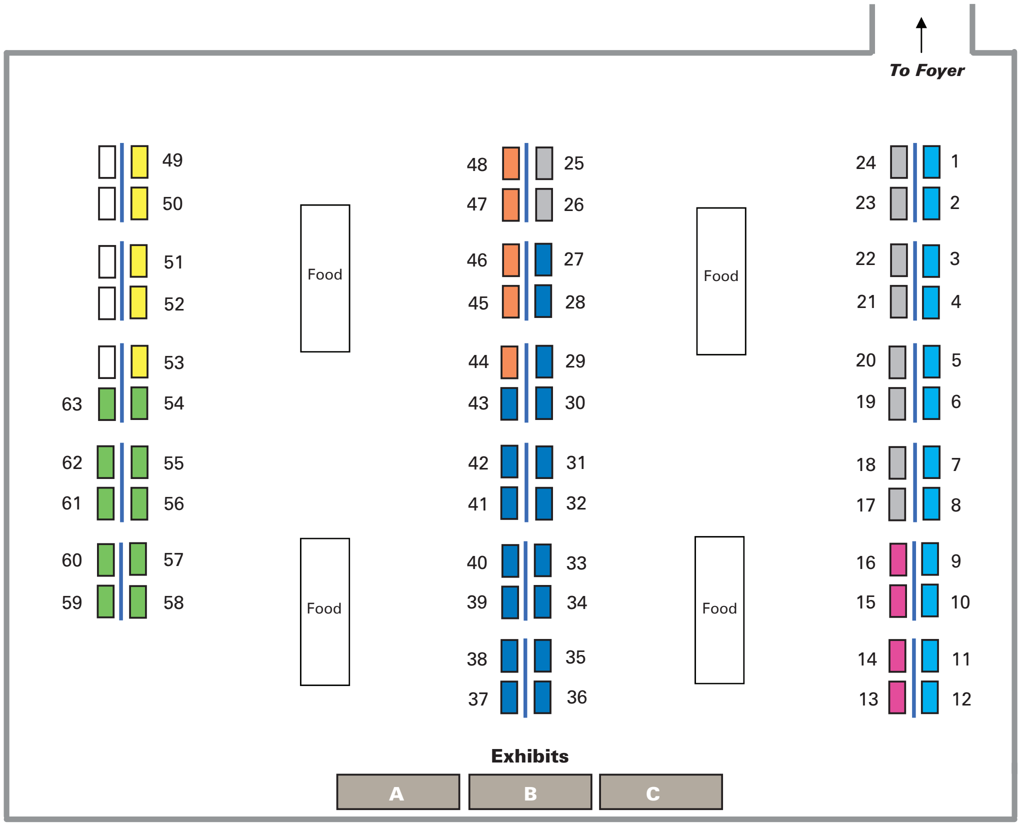

Poster Layout

Session 2

Friday April 19
& Saturday April 20

🟦 A Adaptation & Plasticity in Motor Control

🟥 B Control of Eye & Head Movement

▨ C Disorders of Motor Control

🟦 D Fundamentals of Motor Control

🟧 E Integrative Control of Movement

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