

29th NCM Annual Meeting

Annual Meeting

April 24–27, 2019

Satellite Meeting

April 23, 2019

**Toyama International
Conference Center**

Toyama, Japan



NCM

Society for the
**Neural Control
of Movement**



#NCMToy

www.ncm-society.org

2019 At-A-Glance Satellite & Annual Meeting Schedule



Society for the
Neural Control of Movement

Toyama International Conference Centre

Schedule is subject to change

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr
8:00	Arrivals, Free Time	Registration / Information Desk Open	Registration / Information Desk Open	Registration / Information Desk Open	Registration / Information Desk Open	Registration / Information Desk Open
8:15						
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	Satellite Registration (17:00 - 19:00)	Satellite Meeting	Posters on Display (Session 1) Exhibits on Display	Posters on Display (Session 1) Exhibits on Display	Posters on Display (Session 2) Exhibits on Display	Posters on Display (Session 2)
17:30						
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	Satellite Drinks Reception ANA Crowne Plaza Hotel, 1F Cafe (18:00 - 19:00)	NCM Board Meeting (17:30 - 20:30)	Free Time	Free Time	Free Time and/or Excursions	Free Time
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		Opening Reception The Olive Oil Restaurant (19:30 - 21:30)				Closing Drinks Reception (18:00 - 19:00)
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About NCM

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

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

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

The inaugural NCM Conference took place in April 1991 on Marcos Island, Florida, with roughly 140 attendees. The success of the initial years promoted longevity and expansion of NCM and its conference, both in attendance (now over 250) and the breadth of scientific content. Sessions cover all levels of inquiry--from perception to genetic expression, and from whole organism to intracellular function, while also including computational and theoretical approaches. Sessions have expanded to include a variety of formats and durations to accommodate diverse needs and interests, while poster sessions have been augmented to yield highly popular, vibrant and flexible forums of scientific interchange. This highly regarded and robust conference continues to meet in desirable, family-friendly locations typically in late April/early May every year.

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Letter from the President

Welcome to the 29th annual meeting of the Society for the Neural Control of Movement, held for the first time ever in the Land of the Rising Sun! Although we have gotten as close to Japan as Hawaii on several occasions, until this year we have always asked our Asian colleagues to come to us. This year I am delighted to bring the meeting to them, and to note the highest attendance ever, of NCM members from Japan. Other registrants from a total of 24 countries include attendees from Hong Kong, South Korea, and Taiwan. Prior to the main meeting, Tadashi Isa, Kazuhiko Seki, Daichi Nozaki, and Jun Izawa have organized a satellite meeting on "Predictive coding and active inference." Eye and hand meetings organized and hosted prior to the satellite by Drs. Isa and Seki, respectively, represent another NCM first. We've got lots of great motor control activity even before the main meeting!



Each year, I have had the honor of welcoming new members to the NCM board, and this year is no exception. What was exceptional this year was the large number of outstanding nominations we received. These nominations allow us to maintain a strong and diverse board, and are critical to the NCM Society. New to the board this year are Megan Carey, Champalimaud Center for the Unknown; Kazuhiko Seki, National Center of Neurology & Psychiatry; and Claire Honeycutt, Arizona State University. Pieter Medendorp, Radboud University, will return for a second term. Congratulations to all.

As you know, we also rely on NCM members to ensure a high-quality meeting by proposing excellent scientific content. Once again, the board received many more ideas than could be programmed, including 14 proposals for panels and 71 for individual talks. Overall program design remains similar to past meetings, but one important change to note is an increase in length from two to two and a half hours in the popular daily poster sessions. Of the 200 posters included in the program, one from the front lines of the brain machine interface field stands out. Nathan Copeland is one of a tiny handful of people who has received a cortical implant allowing him, despite a spinal cord injury, to control the movement of a robotic arm and to sense the contact of its fingers with objects. Nathan will present a poster entitled "Insights from an intracortical brain computer interface user." He will also join us for the evening social gatherings. Come learn firsthand what his experience has been like.

The NCM annual meeting also features compelling keynote addresses. The first, on Wednesday morning, is that of the winner of the NCM Early Investigator Award, Gelsy Torres-Oviedo. Gelsy is an assistant professor in bioengineering at the University of Pittsburgh, where she directs the Sensorimotor Learning Laboratory. Her talk is entitled "Sensorimotor adaptation studies to advance neurorehabilitation after stroke." John Kalaska, winner of the NCM Distinguished Career Award, will present the closing keynote address, entitled "Evolving perspectives on the cortical control of reaching movements." John serves as professor in the neuroscience department at the Université de Montréal.

Included among the individual and panel talks are 12 winners of NCM travel awards from trainees at the concluding stage of their Ph.D. program or post-doctoral fellowship. Many of our previous recipients have subsequently taken on prominent roles in the Society, so expect the same from this group. Four of these awardees, Alexander Thomas Mathis, Sam McDougle, Rodrigo Silva Maeda, and Andrea Pack have agreed to write the meeting highlights manuscript, which will be published again this year in the Journal of Neurophysiology. Thanks to Bill Yates and his staff for making this possible.

On the social front, don't forget to sign up for one of the sponsored excursions on Friday afternoon. If you prefer to explore on your own, on-site tourism volunteers will be available to assist in translation, arranging dinners, tours, taxis, etc. We will also continue the pub crawl tradition begun in Dublin, swapping single malt for sake. On Wednesday through Friday, plan to gather at Daigo 醍醐, Amayot Yokochō あまよと横丁, and Uminokami Yamanokami 海の神山の神.

I'd like to encourage everyone to attend a short members' meeting, immediately after the final scientific session on Thursday. In addition to offering the annual report and describing future meeting locations, we will discuss issues of interest to the society at large and seek your feedback about ways to improve our annual meeting. Finally, as always, I am grateful for all the efforts of Marischal De Armond, Michelle Smith, and Podium Conference Specialists without whom this meeting would not be possible. Stop by and give them your thanks!

A handwritten signature in black ink that reads "Lee Miller".

Cordially,
Lee Miller, President

NCM Leadership

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

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

Board Members

Name	Institution	Country	Term
Peter Medendorp ¹	Donders Institute	Netherlands	2016 – 2019
Lena Ting ²	Emory University	USA	2016 – 2019
John van Opstal ²	Donders Institute	Netherlands	2016 – 2019
Robert Turner ¹	University of Pittsburgh	USA	2016 – 2019
Max Berniker ¹	University of Illinois at Chicago	USA	2017 – 2020
Florian Kagerer ¹	Michigan State University	USA	2017 – 2020
Jean-Jacques Orban de Xivry ²	KU Leuven	Belgium	2017 – 2020
Gelsy Torres ¹	University of Pittsburgh	USA	2017 – 2020
Alaa Ahmed ²	University of Colorado	USA	2018 – 2021
Scott Grafton ²	UCSB	USA	2018 – 2021
Dagmar Sternad ²	Northeastern University	USA	2018 – 2021
Adrian Haith ¹	Johns Hopkins University	USA	2018 – 2021

¹ Serving first 3 year term

² Serving second 3 year term

Incoming Board Members

The following members will begin their term at the 2019 Annual Meeting:

Name	Institution	Country	Term
Claire Honeycutt ¹	Arizona State University	USA	2019 – 2022
Kazuhiko Seki ¹	National Center of Neurology & Psychology	Japan	2019 – 2022
Megan Carey ¹	Champalimaud Center of the Unknown	Portugal	2019 – 2022
Pieter Medendorp ²	Donders Institute	Netherlands	2019 – 2022

Officers (Executive Committee)



Lee Miller,
President &
Conference Chair



Kathleen Cullen,
Vice President &
Scientific Chair



Brian Corneil,
Development
Officer



Rachael Seidler,
Treasurer & Secretary

BOARD SERVICE

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

NCM Administration

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

Podium Conference Services

Michelle Smith | Marischal De Armond |
Laurie De Armond

Membership Information

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

Benefits

NCM membership includes the following benefits:

- Opportunity to submit proposals and abstracts for sessions at the Annual Conference
- Opportunity to submit proposals for satellite meetings
- Opportunity to register for Annual NCM Conferences at reduced registration rates
- Access to the member resource database and other members' web services

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

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

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.

Conference	Dates	City	Country	Hotel
28th Annual Meeting*	April 30 – May 4, 2018	Santa Fe, NM	USA	Hilton Buffalo Thunder
27th Annual Meeting*	May 1 – 5, 2017	Dublin	Ireland	The Clayton Hotel Burlington Road
26th Annual Meeting	April 24 – 29, 2016	Montego Bay	Jamaica	Hilton Rose Hall Resort
25th Annual Meeting*	April 20 – 24, 2015	Charleston, SC	USA	Francis Marion Hotel
24th Annual Meeting*	April 21 – 25, 2014	Amsterdam	Netherlands	Grand Hotel Krasnapolsky
23rd Annual Meeting*	April 16 – 20, 2013	San Juan, Puerto Rico	USA	El San Juan Hotel & Casino
22nd Annual Meeting*	April 23 – 28, 2012	Venice	Italy	Hilton Molino Stucky
21st Annual Meeting*	April 26 – 30, 2011	San Juan, Puerto Rico	USA	El San Juan Hotel & Casino
20th Annual Meeting*	April 20 – 25, 2010	Naples, FL	USA	Naples Beach Hotel & Golf Club
19th Annual Meeting*	April 28 – May 3, 2009	Waikoloa, HI	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

Conference	Dates	City	Country	Hotel
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, HI	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	April 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, HI	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 Conference*

Annual Meeting Code of Conduct

As a representative of your institution the standards and code of conduct of your institution are in effect while at the NCM Annual Meeting, Satellite Meeting and all social events. As a reminder, while at the NCM Annual Meeting, the code of conduct and professional standards set by your institution are still in effect.

The Society for the Neural Control of Movement (NCM) encourages open and honest intellectual debate within a welcoming and inclusive atmosphere at the Annual Meeting and through official NCM social media channels. To help maintain an open and respectful community of scientists, NCM does not tolerate illegal or inappropriate behavior at any annual meeting, including violations of applicable laws of the country in which the meeting is taking place. NCM condemns inappropriate or suggestive acts or comments that demean or harass another person by reason of gender, gender identity or expression, sexual orientation, physical appearance, ethnicity/race, religion (or

lack thereof), or that are generally unwelcome or offensive to other members of the community. Sexual language and imagery, unless related to specific scientific discussions, is not appropriate for any conference venue, including talks, workshops, parties, Twitter and other online media. As the NCM Annual Meeting is attended by a wide spectrum of delegates, please be aware of the power dynamic between PIs, post doctoral fellows and students and how that dynamic may affect interactions amongst delegates.

NCM staff will help participants contact hotel/venue security or local law enforcement, provide escorts, or otherwise assist those experiencing harassment to feel safe for the duration of the meeting. We value your attendance.

If you are being harassed or impacted negatively, please contact the NCM staff to discuss your concern.

General Conference Information

Conference Venue

Toyama International Conference Center
1-2 Ote-machi | Toyama-city, Toyama | 930-0084

All conference sessions will take place in this location. The Opening Reception will be held off site at the Olive Oil Restaurant at 1-5-25 Sakuramachi | Apa Villa Bldg 1F a short 15 minute walk from the Toyama International Conference Center.

Registration

SATELLITE MEETING
Satellite Meeting registration fees include a complimentary drink during a drop in gathering on Monday April 22 at the ANA Crowne Plaza hotel, access to the full day meeting with refreshment breaks and a buffet lunch on Tuesday April 23.

ANNUAL CONFERENCE
Annual Conference registration fees include access to all sessions including panel, individual, and poster sessions. Registration also includes daily refreshment breaks, grazing lunches, the Opening Reception at Olive Oil Kitchen Restaurant and the Closing Drinks Reception.

ADDITIONAL TICKETS
Tickets can be purchased separately for your guests and/or children for the Opening Reception, Closing Drinks Reception and Buffet Lunches and excursions. These additional tickets can be purchased from the staff at NCM's Registration Desk.

Name Badges

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

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

Dress Code

Dress is casual for all NCM meetings and social events.

Registration and Information Desk Hours

The NCM Registration and Information Desk, located outside the Main Hall of the Toyama International Conference Center, will be open during the following dates and times:

Monday, April 22	17:00 – 19:00** At the ANA Crowne Plaza lobby
Tuesday, April 23	08:00 – 18:00
Wednesday, April 24	07:30 – 16:00
Thursday, April 25	07:30 – 17:00
Friday, April 26	07:30 – 15:00
Saturday, April 27	07:30 – 17:00

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

Poster Information

ANNUAL MEETING:

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

POSTER SESSION 1

Set-up: Wednesday April 24, 07:30 and 10:00

Remove: Thursday, April 25, between 17:00 and 18:00

POSTER SESSION 2

Set-up: Friday, April 26, between 07:30 and 10:00

Remove: Saturday, April 27 immediately following the poster session at 15:00

Any posters that are not taken down by the removal deadline will be held at the registration desk until the end of the Meeting. Any posters that remain unclaimed by the end of the Meeting will be disposed of.

Information on Poster Authors (Lead), Poster Numbers and Poster Titles begins on page 38. For a complete copy of all the poster abstracts, a digital abstract booklet can be downloaded from the Member Only section of the NCM Website.

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

Staff

NCM staff from Podium Conference Specialists can be identified by orange ribbons on their name badges. Feel free to ask anyone of our staff for assistance. For immediate assistance please visit us at the Registration Desk.

Internet Services

Wireless Internet is available to Annual Meeting delegates for no charge. Simply choose the appropriate WiFi network depending on where you are and enter the password which is the same for all areas.

3F Foyer SSID: **I.C.Hwireless3F**
Main Hall SSID: **TICCMANHALL**
Room 201-204 SSID: **TICC201-204**
Password: **kokusai1**

Kindly note, the WiFi strength is ideal for checking emails and websites but is not strong enough for streaming videos or heavy social media use.

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

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

No Smoking Policy

The Toyama International Conference Center is a completely non-smoking facility. Smoking areas are located outside the conference center.



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Special Meetings & Events

Monday, April 22 18:00 – 19:00

Satellite Drinks Reception

(Satellite Meeting Registrants)

Location: ANA Crowne Plaza Hotel, 1F Café –
Stop by the registration desk in the lobby of the ANA Hotel

Tuesday, April 23 19:30 – 21:30

Opening Reception

Location: Olive Oil Kitchen Restaurant,
1-5-25 Sakuramachi | Apa Villa Bldg 1F

Thursday, April 25 17:00 – 17:30

NCM Members Meeting

Location: Main Hall

Saturday, April 27 18:00 – 19:00

Closing Drinks Reception

Location: Toyama International Conference Center

Opening Reception walking map



NCM Evening Meet up Locations

Join us each evening in a different and unique Toyama restaurant/bar as we explore Toyama by night!

Wednesday April 24

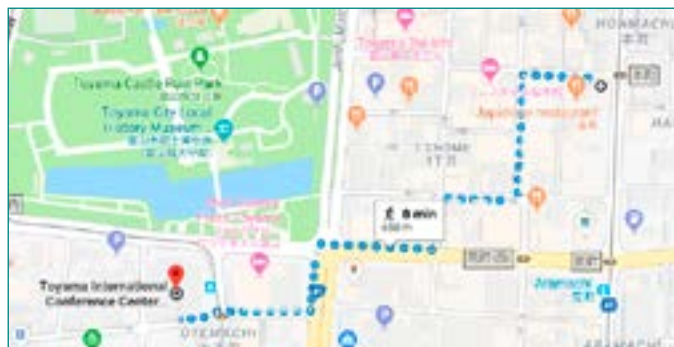
Daigo 醍醐

18:00-24:00

8-3 Honmachi Toyama City
(9-min walk from the TICC)

Daigo is a Japanese sake bar and restaurant, with more than 400 kinds of Japanese sake available.

Website: syusuidaigo.com/toyama



Thursday April 25

AMAYOT Yokochō あまよっと横丁

19:00-24:00

3-2-16 Sogawa Toyama City
(5-min walk from the TICC)

A complex facility that consists of 7 container-style restaurant bars and an open terrace, near the Gland Plaza. There is something for everyone in this unique restaurant/bar!

Website: amayot.jp



Friday April 26

Uminokami Yamanokami 海の神 山の神

17:30-23:00

Address: 1-1-13 Sogawa Toyama city
(5-min walk from the TICC, close to the Daiichi Hotel)

Japanese sake bar and restaurant where guests can enjoy Japanese sake sitting around the Irori-fireplace on tatami mats. Counter seats also available.

Website: www.umiyama.ne.jp

Don't forget to stop by the tourism information desk for recommendations on restaurants, tours, or unique experiences in Toyama.



Conference Excursions

Iwase Tour

April 26, 15:00 – 18:30

Minimum of 15 participants

Price: \$75USD, includes an English speaking guide and transportation

Depart from the Toyama International Conference Center by foot to the Toyama north station. Guests will board a tram to **Iwase** for the short 30 minute transfer. Upon arrival at Iwase, guests will visit the **Masuda brewery**, a sake brewery with a long history in the region and a historically significant sake.

The Iwase district was a thriving port town at the beginning of the Edo period (1603 - 1867) and has examples of **old timber houses** and **traditional shops** throughout the community. These will be observed during the travel through the community.

Guests will return to Toyama aboard a boat for the **night cruise** and will be returned to **Kansui Park** at 18:00. Kansui Park has **vast lawns** in addition to a **spring, waterfall, playground** and the **Tenmon-kyo Bridge**. The park is also known as having the most beautiful Starbucks location in the world!

Itachibawa River Rafting and walking tour

April 26, 15:00 – 17:00

Groups of 8 only

Price: \$55USD, includes an English speaking guide

Depart from the Toyama International Conference Center by foot to the local **Toyama tram**. Following a short tram ride, guests will walk through the shopping district to the **Ishikura-machi Enmei Jizo** where statues preside over springs from the **Itachi River** whose water is believed to cure sickness. Following the visit to the shrine, guests will board a river raft for a short trip down the Itachigawa River to enjoy the cherry blossoms and view of the city. Debarking at the **Matsukawa Riverside**, guests will enjoy the casual stroll back along the river and through the **Toyama Castle Park** until a return to the Toyama International Conference Center.

Toyama Castle Gardens and Tea Ceremony

April 26, 15:00 – 17:00

Minimum of 4 participants/Maximum of 16 participants

Price: \$40USD, includes an English speaking guide

Depart from the Toyama International Conference Center by foot and begin with a stroll through the **Castle Park** immediately across from the TICC. While enjoying the stroll through the Castle grounds, the guide will share information of interest and history. Toyama Castle Park offers striking views of the moat and tower of **Toyama Castle**. The Castle was once the residence of the Maeda clan of the Toyama Domain of the Edo period (1603-1867).

Guests will enjoy time in the **Sato memorial art museum** and will experience a short traditional **tea ceremony** with green tea and sweets before returning to the Toyama International Conference Center.





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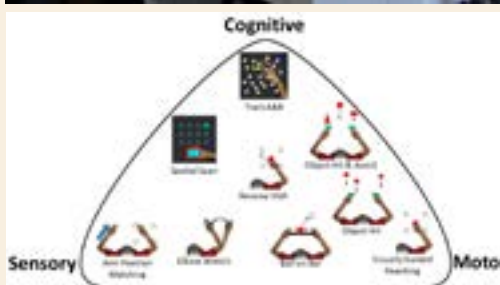
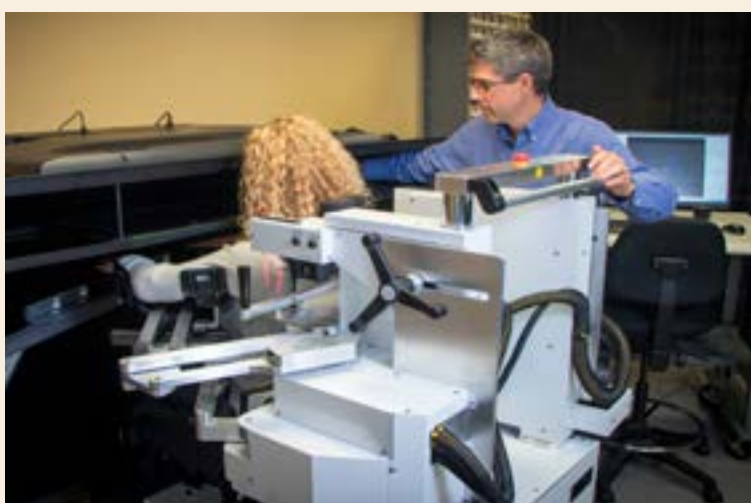
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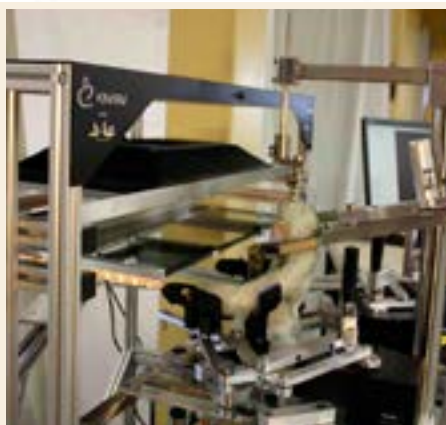
KINARM End-Point Lab (AHC)

KINARM Exoskeleton Lab



KINARM Standard Tests - NEW release!

NHP KINARM Exoskeleton Lab



富山 NCMでは、私達の独占的代理店である
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Satellite Meeting Schedule

NCM Satellite Meeting, Toyama, Japan
April 22 & 23, 2019

Scientific session will be held at the **Toyama International Conference Center**

Predictive coding and active inference to know and explore the world

Exploration is innate to our motor control and motor learning systems. A central computational function of our brain is to proactively generate action to gain valuable sensory states rather than passively react to changes of the environment. In this function, the optimal inference via integration of the prediction and the feedback information from the external world plays a critical role. A question here is how our nervous system for motor function embeds this computation.

In the past two decades, a normative approach on motor control and learning has illustrated that the brain is capable of controlling the body in a stochastically optimal manner by integrating multimodal sensory information every time seconds. Indeed, the Bayesian theory, the Kalman filtering theory, as well as the LQG theory have provided us with a unified computational account of the motor control. However, the block diagram view of the computational anatomy of the brain might miss something important buried in the sophistication in the hierarchical architecture of the motor nervous system.

The goal of this satellite meeting is to discuss how the computational integrity of the motor control system is achieved with the predictive coding of the sensory outcome and errors which are embedded differently among multiple layers of hierarchical structure in the sensorimotor transformation mediated by the nervous system. To explore this view, we adopt a multi-disciplinary approach by getting together with the robot scientists, the computational/behavioral scientists, and the neurophysiologists.

The satellite is organized by

Tadashi Isa, *Kyoto University*

Kazuhiko Seki, *National Institute of Neuroscience*

Daichi Nozaki, *The University of Tokyo*; and

Jun Izawa, *Tsukuba University*

Monday, April 22, 2019

17:00 – 19:00

Satellite Registration

ANA Crowne Plaza Hotel Lobby

18:00 – 19:00

Satellite Drinks Reception

ANA Crowne Plaza 1F Café

Tuesday, April 23, 2019

08:00 – 08:30

Registration

08:30 – 09:30

Tutorial Lecture

A theory of how active behavior stabilizes neural activity: Neural gain modulation by closed-loop environmental feedback

Taro Toyoizumi & Takuya Isomura, *RIKEN CBS*

09:30 – 10:00

Coffee Break

10:00 – 11:50

SESSION 1: *Active inference in broad perspective*

10:00 – 10:30

Cognitive neurorobotics studies using the framework of predictive coding and active inference

Jun Tani, *Okinawa Institute of Science and Technology*

10:30 – 11:00

Neuronal attractor dynamics: coupling perception, movement generation, and learning

Yulia Sandamirskaya, *ETH*

11:00 – 11:30

Lateralized modulation of responses to sensory consequences of voluntary actions

Roy Mukamel, *Tel-Aviv University*

11:30 – 11:50

Large-scale cortical networks for hierarchical prediction in coding in the primate brain

Zenas Chao, *Kyoto University*

11:50 – 13:00

Lunch

13:00 – 14:40	SESSION 2: Active inference in the multiple sensorimotor loops	16:40 – 17:00	
13:00 – 13:30			<i>Driving limb control principles using a neuromechanical Drosophila model</i> Victor Lobato-Rios, <i>EPFL</i>
	<i>Spinal and cortical neural mechanism for active inference in volitional movement</i> Kazuhiko Seki, <i>National Center for Neurology & Psychology</i>	17:00 – 17:15	Transition Time
13:30 – 14:00		17:15 – 18:15	Keynote Lecture
	<i>Goal-directed adaptive motor control in mice</i> Mackenzie Mathis, <i>Harvard University</i>		<i>Computational models for learning from a small sample</i> Mitsuo Kawato, <i>ATR</i>
14:00 – 14:20		19:30 – 21:30	Opening Reception for Annual Meeting
	<i>Predictive eye movement control in fish and humans</i> Yutaka Hirata, <i>Chubu University</i>		Please Note: If you registered to attend the Satellite Meeting ONLY and want to attend the dinner, tickets can be purchased at the registration desk.
14:20 – 14:40			
	<i>The somatosensory cortex encodes anticipatory signal during voluntary movement</i> Tatsuya Umeda, <i>National Center for Neurology & Psychology</i>		
14:40 – 15:10	Coffee Break		
15:10 – 17:00	SESSION 3: Predictive motor control viewed from active inference		
15:10 – 15:40			
	<i>Predictive setup of implicit sensorimotor processing according to tasks and environments</i> Hiroaki Gomi, <i>NTT</i>		
15:40 – 16:10			
	<i>Sensory-motor reverberating circuit controls perception</i> Masanori Murayama, <i>RIKEN CBS</i>		
16:10 – 16:40			
	<i>Predictive sensing: The role of motor signals in vestibular processing during active movements</i> Kathleen Cullen, <i>Johns Hopkins University</i>		

Annual Meeting Schedule

All sessions will be held at the Toyama International Conference Center

DAY 1 Tuesday, April 23, 2019

19:30 – 21:30 Opening Reception

Off Site: **Olive Oil Kitchen Restaurant**,
1-5-25 Sakuramachi | Apa Villa Bldg 1F
(see walking map on page 8)

DAY 2 Wednesday, April 24, 2019

08:00 – 10:00 Session 1, Panel I

Motor sequence preparation and control: From population dynamics to whole brain representations

Katja Kornysheva¹, Mark Churchland², Bence Olveczky³, Atsushi Yokoi⁴

¹Bangor University, ²Columbia University, ³Harvard University, ⁴National Institute of Information and Communications Technology

Discussant: Jörn Diedrichsen, Western University

10:00 – 10:30 Break

10:30 – 11:00 Early Career Award Presentation

Sensorimotor adaptation studies to advance neurorehabilitation after stroke

Gelsy Torres-Oviedo
University of Pittsburgh

11:00 – 13:00 Session 2, Panel II

Action in Motion: Decisions and actions as we move through our world

W. Pieter Medendorp¹, Andrea Green², Friedl De Groote³, Alexander Gail⁴

¹Radboud Univ Nijmegen, ²University of Montreal, ³KU Leuven, ⁴German Primate Center

Discussant: Kathleen Cullen, Johns Hopkins University

13:00 – 15:30 Session 3, Poster 1a and Lunch

15:30 – 17:30 Session 4, Individual I

Generation of compound movements by motor cortex

Presenting Author: Andrew Zimnik

Authors: Andrew Zimnik¹, Mark Churchland¹

¹Columbia University

Transient grasp force signals in motor cortex during extended object interaction

Presenting Author: Brian Dekleva

Authors: Brian Dekleva¹, Jennifer Collinger¹

¹University of Pittsburgh

Contrasting roles of PMd and A5 to feedback responses to mechanical disturbances of the limb in non-human primates

Presenting Author: Tomohiko Takei

Authors: Tomohiko Takei¹, Stephen Lomber², Douglas Cook³, Stephen Scott³

¹Kyoto University, ²Western University, ³Queen's University

Dynamical influence of premotor and primary motor cortex during movement

Presenting Author: Raina D'Aleo

Authors: Raina D'Aleo¹, Adam Rouse², Marc Schieber², Sridevi Sarma¹

¹Johns Hopkins, ²University of Rochester

Feedforward and feedback control share an internal model of the arm's dynamics

Presenting Author: Rodrigo Maeda

Authors: Rodrigo Maeda¹, Tyler Cluff², Paul Gribble¹, J. Andrew Pruszynski¹

¹Western University, ²University of Calgary

Intracortical microstimulation parameters affect tactile perception

Presenting Author: Christopher Hughes

Authors: Christopher Hughes¹, Sharlene Flesher², Jeffrey Weiss¹, Sliman Bensmaia³, Robert Gaunt¹

¹University Of Pittsburgh, ²Stanford University, ³University Of Chicago

DAY 3 Thursday, April 25, 2019

08:00 – 10:00 Session 5, Panel III

Cerebellar computation 50 years after Marr-Albus: where are we now?

Terence Sanger¹, Mitsuo Kawato², Mackenzie Mathis³, Huu Hoang², Kazuo Kitamura⁴

¹University of Southern California, ²ATR Computational Neuroscience Laboratories, ³Harvard University, ⁴University of Yamanashi

Discussant: Mitsuo Kawato, *ATR Computational Neuroscience Laboratories*

10:00 – 10:30 Break

10:30 – 12:30 Session 6, Panel IV

New perspectives on the role of the superior colliculus in visually-guided motor behavior

Mayu Takahashi¹, John van Opstal², Neeraj Gandhi³, Ziad Hafed⁴

¹Tokyo Medical and Dental University, ²Radboud University Nijmegen, ³University of Pittsburgh, ⁴Tübingen University

Discussant: Doug Munoz, *Queens University*

12:30 – 15:00 Session 7, Poster 1b and Lunch

15:00 – 17:00 Session 8, Panel V

Applications of deep learning in motor neuroscience

Chethan Pandarinath¹, Laura Driscoll², Alexander Mathis³, Nidhi Seethapathi⁴

¹Emory University and Georgia Institute of Technology, ²Stanford University, ³Harvard University, ⁴University of Pennsylvania

Discussant: Andrew Pruszynski, *Western University*

17:00 – 17:30 NCM Members Meeting

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

DAY 4 Friday, April 26, 2019

08:00 – 10:00 Session 9, Individual II

Precise spike-timing codes for vocal motor control

Presenting Author: Andrea Pack

Authors: Andrea Pack¹, Bryce Chung¹, Muneeb Zia², Coen Elemans³, Muhannad Bakir², Samuel Sober¹

¹Emory University, ²Georgia Institute of Technology, ³University of Southern Denmark

Motor variability predicts motor learning in complex real-world task

Presenting Author: Shlomi Haar

Authors: Shlomi Haar¹, Aldo Faisal¹

¹Imperial College London

Motor expertise promotes transfer of visuo-motor compensations acquired during prism exposure

Presenting Author: Lisa Fleury

Authors: Lisa Fleury¹, Damien Pastor¹, Patrice Revol¹, Ludovic Delporte¹, Yves Rossetti¹

¹Centre of Research in Neurosciences of Lyon

Global disinhibition as a key mechanism for the recovery of hand functions after spinal cord injury

Presenting Author: Tadashi Isa

Authors: Tadashi Isa¹, Reona Yamaguchi¹, Toshinari Kawasaki¹, Satoko Ueno¹, Masahiro Mitsuhashi¹, Zenas Chao¹

¹Kyoto University

Dynamic sonomyographic imaging of the residual musculature provides proportional control for upper-extremity amputees

Presenting Author: Wilsaan Joiner

Authors: Wilsaan Joiner¹, Ananya Dhawan¹, Biswarup Mukherjee¹, Shriniwas Patwardhan¹, Nima Akhlaghi¹, Gyorgy Levay², Michelle Harris-Love¹, Siddhartha Sikdar¹

¹George Mason University, ²Infinite Biomedical Technologies

Neural basis of location-specific pupil luminance modulation

Presenting Author: Doug Munoz

Authors: Doug Munoz¹, Chin-An (Josh) Wang^{1,2}

¹Queen's University, ²Department of Anesthesiology, Shuang Ho Hospital, Taipei Medical University

10:00 – 10:30 Break

Annual Meeting Schedule

10:30 – 12:30 Session 10, Panel VI

Multi-dimensional dexterous hand function and recovery

Jing Xu¹, Marco Santello², Firas Mawase³, Shinichi Furuya⁴

¹Johns Hopkins University, ²Arizona State University, ³Technion - Israel Institute of Technology, ⁴Sony Computer Science Laboratories Inc., Sophia University

Discussant: Marc Schieber, University of Rochester

12:30 – 15:00 Session 11, Poster 2a and Lunch

15:00 – 17:00 Free time and Ticketed Excursions

DAY 5 Saturday, April 27, 2019

08:00 – 10:00 Session 12, Panel VII

Beyond motor errors: New perspectives on the role of the cerebellum in learning

Richard Ivry¹, Court Hull², Mark Wagner³, Amanda Therrien⁴, Samuel McDougale⁵

¹University of California, ²Duke University Medical School, ³Stanford, ⁴The Johns Hopkins School of Medicine, ⁵University of California, Berkeley

Discussants: Richard Ivry, University of California & Jörn Diedrichsen, Western University

10:00 – 10:30 Break

10:30 – 12:30 Session 13, Individual III

Encoding and control of motor prediction and feedback in the cerebellar cortex

Presenting Author: Martha Streng

Authors: Martha Streng¹, Laurentiu Popa¹, Timothy Ebner¹

¹University of Minnesota

Spatial and temporal locomotor learning in the mouse cerebellum

Presenting Author: Megan Carey

Authors: Dana Darmohray¹, Jovin Jacobs¹, Hugo Marques¹, Megan Carey¹

¹Champalimaud Neuroscience Programme

Implicit adaptation is driven by inverse model learning, not forward model learning

Presenting Author: Alkis Hadjiosif

Authors: Alkis Hadjiosif¹, John Krakauer¹, Adrian Haith¹

¹Johns Hopkins University

Somatosensory cortex participates in the consolidation of human motor memory

Presenting Author: David Ostry

Authors: Neeraj Kumar¹, Timothy Manning², David Ostry³

¹McGill University and Indian Institute of Technology Gandhinagar, ²McGill University, ³McGill University and Haskins Laboratories

Underlying mechanisms of reward-based motor learning

Presenting Author: Peter Holland

Authors: Peter Holland¹, Olivier Codol¹, Joseph Galea¹

¹University of Birmingham

Sleep's benefit on multiple forms of locomotor learning

Presenting Author: Julia Choi

Authors: Julia Choi¹, Rebecca Spencer¹, Gabriela Borin¹

¹University of Massachusetts Amherst

12:30 – 15:00 Session 14, Poster 2b and Lunch

15:00 – 17:00 Session 15, Panel VIII

Complex material properties of muscle: artifacts or features?

Madhusudhan Venkadesan¹, Neville Hogan², Kiisa Nishikawa³, Lena Ting⁴

¹Yale University, ²Massachusetts Institute of Technology, ³Northern Arizona University, ⁴Emory University & Georgia Tech

Discussant: Simon Giszter, Drexel University

17:00 – 18:00 Session 16, Keynote Address

Evolving perspectives on the cortical control of reaching movements – Random observations and recollections from a reasonably OK career

John Francis Kalaska, Université de Montréal

18:00 – 19:00 Closing Drinks Reception

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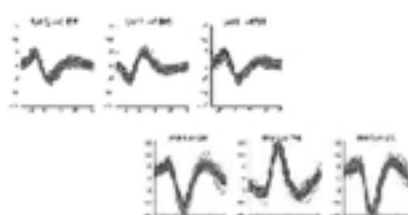
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Electrode material	Pt (99.9%)	Electrode material	Pt (99.9%)
Electrode pitch	2.5 mm \sim	Electrode pitch	1.0 mm \sim (in 0.5 mm increment)
Electrode layout	Free	Electrode layout	Free
Sheet thickness	0.05x2 mm	Sheet thickness	0.05x2 mm
Lead wire material	Stainless steel	Lead wire material	Stainless steel
Lead wire length	Free	Lead wire length	Free
Connector	Specify	Connector	Specify
Ref. G.	Depend on needs	Ref. G.	Depend on needs

Micro Cuff Electrode

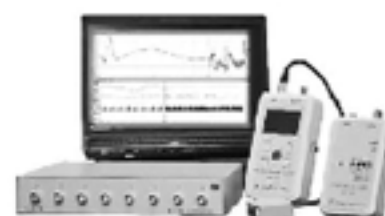


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Pitch of electrodes	Free
Lead wire material	Stainless steel, etc.
Lead wire length	Free
Connector	Specify

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Team & Individual Oral Abstracts

Wednesday April 24, 2019

08:00 – 10:00 Session 1, Panel I

Motor sequence preparation and control: From population dynamics to whole brain representations

Katja Kornysheva¹, Mark Churchland², Bence Olveczky³, Atsushi Yokoi⁴

¹Bangor University, ²Columbia University, ³Harvard University, ⁴National Institute of Information and Communications Technology

The ability to acquire and retrieve action sequences from memory fluently is essential for daily functioning. While research on 'serial behaviour' has been conducted for almost 140 years, a vigorous debate on its neural basis continues. Recent analytical progress with regard to neural population dynamics and neuroimaging patterns have led to significant advances in the field, revealing fundamental neural principles behind sequence preparation and control across brain regions and at different levels of the motor hierarchy. Here we present research across human and animal models to synthesize conceptual advances in the field. First, Mark Churchland will present new findings on population dynamics in the SMA and in M1 during extended movements in non-human primates. He will show that population dynamics are very different in these areas, in ways predicted by network models performing different classes of computation. Specifically, neural trajectories in the SMA, but not in M1, anticipate behaviour that will diverge in the future. The population structure underlying this computational property contributes well-known properties of single-neuron tuning, such as 'representations' of time within a longer movement. Second, Atsushi Yokoi will present a series of studies which provide new insights into how human neocortex organizes movement sequences hierarchically. Specifically, Atsushi will demonstrate that the pattern in M1 represents individual finger movements, whereas premotor and parietal cortices show a mixture of chunk, sequence and finger transition representations. He will discuss how the use of representational parcellation enables a model-free division of these non-primary motor cortices into separate clusters, each showing a unique representation along the stimulus-to-action gradient. Third, Bence Olveczky will present laboratory studies which enable training of

rodents to generate complex motor sequences using operant conditioning paradigms. Bence will report on the results from circuit function manipulation to determine their role in generating learned movement sequences. He will discuss this work in the context of his previous discoveries related to sequence control in songbirds, which suggest an independent control of the timing of sequences. Finally, Katja Kornysheva will show how non-invasive electrophysiology in humans can be used to readout the structure of actions before sequence initiation. Specifically, she will discuss findings suggesting that sequential action patterns are competitively queued at a trial-by-trial level during sequence preparation according to sequence position. Katja will argue that this pattern activation gradient during preparation reflects a transferable temporal template of a sequence and bears on performance accuracy. In sum, this session will provide new avenues for interdisciplinary discussion and collaboration.

10:30 – 11:00 Early Career Award Winner Talk

Sensorimotor adaptation studies to advance neurorehabilitation after stroke

Gelsy Torres-Oviedo, *University of Pittsburgh*

My long-term research goals are to advance the current understanding of walking deficits post-stroke and develop treatments to improve their gait. My approach has been to combine quantitative tools from engineering and experimental work based on post-stroke neurology. I believe that this multidisciplinary approach is needed to advance the field of gait rehabilitation; provide insights into patients' motor deficits; and generate predictions of treatment outcomes on an individual basis. At NCM 2019, I will focus the discussion on my work related to the generalization of movements from trained to untrained situations. I will start presenting a detailed characterization of muscle activity (i.e., EMGs) associated to errors elicited by introducing a split-belt environment of two opposite directions (i.e., right leg moving faster than the other or vice versa). This quantification revealed that motor patterns upon split-belt removal after sensorimotor recalibration are the same as those first experienced upon introduction of the opposite perturbation (Iturralde and Torres-Oviedo, bioRxiv 2018). From a clinical perspective, our detailed EMG characterization is relevant because it indicates clinical targets post-stroke and has also revealed a partial dissociation in the execution and recalibration of motor commands: the execution requires intact cerebral

structures, whereas the recalibration does not (deKam, Iturralde, and Torres-Oviedo, bioRxiv 2019). From a basic science perspective, our findings are important because they support the theory that 1) people develop motor memories associated to specific walking conditions (e.g., split-belt environments of different direction) and that 2) errors upon introduction or removal of a new environment enable the transition between motor memories appropriate to the context at hand. Based on this theory, I will discuss the effect of errors of different magnitude and direction on the generalization of motor patterns from the treadmill to overground (model predictions and empirical results will be contrasted). Overall, my work is just an example of scientific efforts to address clinical problems through a combination of computational and laboratory-based studies. I envision that my research will contribute to the progress of gait rehabilitation and ultimately improve the quality of life of patients and caregivers.

11:00 – 11:30 Session 2, Panel II

Action in Motion: Decisions and actions as we move through our world

W. Pieter Medendorp¹, Andrea Green², Friedl de Groote³, Alexander Gail⁴

¹Radboud Univ Nijmegen, ²University of Montreal, ³KU Leuven ⁴German Primate Center

Living in a dynamic world, we are continuously in motion, avoiding obstacles, and interacting with objects of interest. How do we perform such complex tasks? Experiments under simplified laboratory conditions, with body movements restrained, indicate that our behavioral repertoire is controlled by internal models and sensory feedback, shaped by past experience. But will the observed principles also apply to more complex real-life conditions, such as walking or driving? In the real world, multiple sensory and motor systems must be used in synergy in order to accurately estimate our motion and execute actions in an unpredictable environment. Do our response decisions anticipate the effects of self-motion? How do we evaluate body and world dynamics when coordinating actions with body motion? In recent years, several novel approaches have been employed to identify how real-world body motion is coordinated with action selection and goal-directed oculomotor and skeletomotor control. This session will inform NCM members about these findings, covering human behavior and imaging, neuronal recordings in monkeys, and computational

modeling. MEDENDORP will start the session with a brief overview. Subsequently, he will discuss the mechanisms for effector selection when humans are in motion. He will show that accelerations of the body are taken into account when deciding which hand to use for a reach, or where to look with the eyes, by modulating activity in cortical areas involved in response selection. GREEN will explore the mechanisms by which vestibular signals are processed to compensate for body motion during reach execution. She will show that vestibular signals contributing directly to online reach control are appropriately transformed from a head- to a body-centered reference frame. She will also provide evidence that the mechanisms by which such transformed vestibular signals contribute to online feedback corrections involve “smart” processing, taking into account knowledge of the biomechanical properties of the limb. DE GROOTE will discuss standing and walking balance control in response to external perturbations. She uses a blended experimental and computational approach. First, she will show how sensory noise and postural sway may contribute to age-related alterations in the kinematic strategy to restore balance after a perturbation of standing. Next, she will discuss how muscle responses in perturbed walking are adjusted during the gait cycle to meet mechanical demands and how these responses change with age. GAIL will discuss spatial encoding of reach goals during walk-and-reach movements. He will show that peripersonal space is expanded towards reach targets beyond immediate reach when walking towards them. Next, he will present wireless neural recordings parietofrontal cortex of rhesus monkeys during walk-and-reach movements, suggesting equivalent encoding of reach goals within and beyond immediate reach in the same reach areas.

Team & Individual Oral Abstracts

Wednesday April 24, 2019

15:30 – 17:30 Session 4, Individual I

Generation of compound movements by motor cortex

Andrew Zimnik¹, Mark Churchland¹

¹Columbia University

Before voluntary movement, population activity within motor cortex establishes a preparatory state that is proposed to seed movement-generating dynamics. Yet this view derives largely from discrete movements; real-world movements are often executed within longer sequences. In such cases, does motor cortex simply prepare and execute each component movement sequentially? Or are movements prepared and executed holistically, as a single ‘chunk’? We trained a monkey to perform single reaches and sequences of two reaches and recorded from 218 motor cortex neurons. A delay period allowed for preparation between the onset of the target(s) and a go cue. Behavior was consistent with a holistic strategy: sequences completed rapidly (within ~500 ms) with almost no pause between reaches. Muscle activity evolved continuously with no intervening pause or plateau. We next asked whether, at the neural level, reaches were prepared and executed sequentially or holistically. We leveraged the recent finding that although preparation and execution-related activity overlap at the single-neuron level, they occupy orthogonal neural subspaces and can thus be cleanly segregated at the population level. Critically, this allows observation of preparation both before the first reach and (if present) during the sequence. The sequential hypothesis predicts that preparatory activity before the first of two reaches should resemble preparatory activity when generating that reach alone. Preparation should then re-occur just before the second movement (i.e., as the first movement is ending). In contrast, the holistic hypothesis predicts that the full compound movement is prepared during the delay; thus, preparatory activity before the first reach should differ from that when generating that reach alone. Furthermore, because preparation during the delay period pertains to the entire sequence, a second bout of preparation is unnecessary (just as it is unnecessary during normal discrete movements). Despite the seemingly holistic nature

of behavior and muscle activity, neural activity obeyed the predictions of the sequential hypothesis. Delay-period preparatory activity reflected the location of the first target, regardless of the presence or direction of a second reach. Furthermore, preparatory activity diminished prior to the onset of the first reach, then reappeared. This reappearance occurred during the first reach then again diminished before the onset of the second reach. This reappearance was never observed for single reaches. These results demonstrate a surprising feature of motor cortex: even when performing simple, well-learned motor sequences, each movement is prepared and executed sequentially. Rapid sequencing was not achieved through a holistic strategy but rather by preparation for the next movement beginning as the previous movement was still underway. Computations related to sequence ‘chunking’ must therefore be performed upstream in more cognitive regions.

Transient grasp force signals in motor cortex during extended object interaction

Brian Dekleva¹, Jennifer Collinger¹

¹University of Pittsburgh

The most fundamental purpose of upper limb control is to interact with and manipulate objects. However, most studies on the cortical control of reach and grasp use experimental paradigms that examine only arm movement (e.g. cursor-based control) or grasp (e.g. isometric force production) in isolation. It is not clear how insights about cortical function gained from these tasks might apply to more complex behaviors involving extended manipulation and transport of objects. Supporting this concern about generalizability is a recent result showing that cortical signals related to grasp force are not present during the transport phase of an object “grasp and carry” task (Downey, et al., 2018). Here we extend the results of that study by examining the population activity of human primary motor cortex (M1) during simultaneous control of grasp force and arm translation. We recorded intracortical neural responses from both the hand and arm areas of M1 as a human subject with quadriplegia attempted to mimic various object-oriented tasks presented in a virtual environment. The range of tasks included: (1) applying different grasp forces to a stationary object, (2) transporting an object from one location to another at different grasp force levels, and (3) dynamically adjusting grasp force during object transport. In all conditions

involving arm translation--regardless of grasp condition--we observed a consistent relationship between the neural activity and the direction of intended movement. That is, the signals related to arm translation were unaffected by features of grasp. Conversely, the signals related to grasp force were highly dependent on task context. During grasp of a stationary object, cortical signals showed direct correlation with the attempted grasp force at all times throughout object interaction (from pre-contact until object release). In contexts involving object transport, we observed the same grasp-related signals (i.e. the same neural patterns), but they were highly transient and displayed correlations with the intended grasp force only during periods of force change. Importantly, this transience did not arise due to interference between translation- and force-related signals; they occupied orthogonal dimensions in neural state space and could be modulated independently. Instead, our results suggest that cortex can recruit additional networks outside of M1 (perhaps subcortical structures) in order to sustain force production without requiring continuous descending drive. This apparent “automatic” maintenance of force production may be especially useful during complex behaviors that require split attention between multiple control modalities.

feedback control by exploring how deactivation in these cortical regions (i.e. cooling to inhibit neural activity) impact feedback control in non-human primates. To give functional implications to the behavioral results, we generated an optimal feedback control model to observe how deactivation of model parameters (i.e. reductions in values) impact feedback corrections to mechanical disturbances. Results show that deactivation of the “control policy” impaired both accuracy and response speed, whereas deactivation of “state estimation” impaired accuracy but not response speed. Next, we trained a rhesus monkey to perform a unilateral arm postural perturbation task, in which the monkey was required to maintain arm posture while responding to mechanical perturbations. Under normal conditions, the monkey made a quick and accurate response after each disturbance to return the hand to the spatial goal. When PMd was cooled the monkey displayed impairments in both accuracy and response speed. In contrast, when A5 was cooled the monkey displayed impairments in accuracy, but not response speed. These results provide causal support for the role of both regions in generating goal-directed motor corrections, and suggest that PMd and A5 have different functions in feedback control: contributions to the control policy and state estimation, respectively.

Contrasting roles of PMd and A5 to feedback responses to mechanical disturbances of the limb in non-human primates

Tomohiko Takei¹, Stephen Lomber², Douglas Cook³, Stephen Scott³

¹Kyoto University, ²Western University, ³Queen's University

A hallmark of our motor system is the ability to generate a broad range of motor actions, and importantly, flexibly adjust these movements to manage changes or disturbances in our environment. Recent studies have explored this process by using small mechanical disturbances during motor actions, highlighting the surprising speed and complexity of goal-directed motor corrections. Corresponding neurophysiological studies implicate a broad network in fronto-parietal cortices in these feedback corrections, but the specific role of different cortical regions is poorly understood. Primary motor cortex is commonly recognized as important for feedback control, but far less is known on how other cortical regions contribute to these goal-directed motor corrections. Here we investigate the role of dorsal premotor cortex (PMd) and parietal area 5 (A5) in

Team & Individual Oral Abstracts

Wednesday April 24, 2019

Dynamical influence of premotor and primary motor cortex during movement

Raina D'Aleo¹, Adam Rouse², Marc Schieber², Sridevi Sarma¹

¹Johns Hopkins, ²University of Rochester

Investigating what neurons in different motor regions encode during movement provides insight into the complex sensorimotor control system. While there are anatomical distinctions between premotor cortex (PM) and primary motor cortex (M1) attributed to their upstream and downstream pathways and cytoarchitecture, their functional distinction within the motor pathway is less clear as they have largely been studied independently using static correlations between kinematics and neural activity. These analysis methods have limited ability to interpret dynamical interaction and influence across these regions. A recent approach to studying neuronal activity during movement is to construct a dynamical systems model (DSM), wherein cortical activity is perceived as a trajectory through a state-space, initiated by a preparatory state (initial condition), where a movement in state-space represents a movement in physical space. This approach allows for the populations to influence each other in a dynamical manner, which in turn generate movement. To date, applications of DSM have been narrow in scope, characterizing activity in single regions and over brief time periods during which no abrupt events (e.g. movement onset) or stimuli (e.g. visual cue) occur. To capture long time periods, a different DSM is constructed in each time period that modulate with different external events (Elsayed, 2016). Here, we expand the DSM framework to allow for a single model to characterize neural dynamics (i) over the entire trial during which multiple events occur and (ii) between multiple brain regions. The multiple events are modeled as exogenous inputs entering the motor regions, PM and M1, whose firing rates are in general coupled and evolve dynamically to generate kinematic output. We apply our general DSM approach to neuronal data captured in two nonhuman primates executing a reach-to-grasp task and demonstrate the model's ability to reconstruct population activity in both PM and M1 simultaneously in addition to kinematic trajectories. Evaluation of the

evolution of the DSM solution allows us to estimate functionally distinct influence of each cortical region on the neural and kinematic state throughout a movement.

Feedforward and feedback control share an internal model of the arm's dynamics.

Rodrigo Maeda¹, Tyler Cluff², Paul Gribble¹, J. Andrew Pruszynski¹

¹Western University, ²University of Calgary

The nervous system can generate a variety of novel movement patterns in many different contexts. Complicating this process are the mechanical interactions that arise between moving limb segments. For example, producing pure elbow movement requires generating torques not only at the elbow but also at the shoulder to counter interaction torques that arise at the shoulder when the forearm rotates [1]. Our long-term goal is to establish whether and how neurons in the primate sensorimotor system account for and learn intersegmental dynamics during reaching (i.e. feedforward) and reflexive (i.e. feedback) control. Here we present findings in humans and monkeys showing that learning novel intersegmental dynamics during feedforward control transfers to feedback control, which suggests that these two processes engage a common neural circuit [2]. Forty-five humans and two macaque monkeys generated pure elbow flexion and extension movements using a robotic exoskeleton (KINARM, BKIN Tech) that permits shoulder and elbow rotation in the horizontal plane. They first did so with the shoulder free to move (baseline phase). We then mechanically locked the shoulder joint and participants repeated the same pure elbow movements (adaptation phase). Locking the shoulder joint eliminates the interaction torques that arise at the shoulder during forearm rotation, removing the need to generate shoulder torque and thus activate shoulder muscles. Last, we unlocked the shoulder joint and participants again had to counter the intersegmental dynamics to generate pure elbow movements (post-adaptation phase). In fifteen percent of trials in all phases, we applied mechanical perturbations that caused pure elbow motion to evoke reflex responses. Importantly, all joints were free to move in perturbation trials such that participants only experienced the altered intersegmental dynamics in reaching trials. In the baseline and post-adaptation phases, we found robust activation of shoulder flexor muscles for pure elbow flexion trials and shoulder extensor muscles for pure elbow

extension trials - as required to counter the intersegmental dynamics. Perturbation trials in the baseline phase revealed that feedback responses also appropriately countered the intersegmental dynamics. In the adaptation phase, we found a substantial reduction in shoulder muscle activity during both elbow flexion and extension trials - as appropriate for the altered intersegmental dynamics. Feedback responses of shoulder muscles were also reduced even though they were never trained to do so. We are now dissecting the neural circuit that underlies this learning and transfer via large scale neural recordings in the monkey primary motor cortex [3]. References: [1] Maeda et al. (2017). *Journal of Neurophysiol.* 118,1984-1997. [2] Maeda et al. (2018). *Journal of Neurosci.* DOI:10.1523/JNEUROSCI.1709-18.2018. [3] Pruszynski et al. (2011). *Nature* 478, 387-390.

Intracortical microstimulation parameters affect tactile perception

Christopher Hughes¹, Sharlene Flesher², Jeffrey Weiss¹, Sliman Bensmaia³, Robert Gaunt¹

¹University Of Pittsburgh, ²Stanford University, ³University Of Chicago

Intracortical microstimulation (ICMS) in somatosensory cortex (S1) can restore tactile percepts in people with spinal cord injury (Flesher 2016). These artificial somatosensory percepts provide feedback in a bidirectional brain-computer interface (BCI) to restore natural integrative control of movement. We have found that with stimulus trains of fixed amplitude and frequency, the tactile percepts elicited by ICMS in S1 vary by electrode in intensity and quality but remain consistent over time. However, cortical activity varies spatiotemporally in response to peripheral mechanical inputs. Here, we sought to characterize how stimulus trains with different fixed frequencies and amplitudes, or trains that varied in frequency and amplitude dynamically, affected the intensity and naturalness of elicited sensations. Ultimately, the goal of this work is to produce sensations that are more naturalistic and improve the function of a bidirectional BCI system. A human participant with a C5/C6 spinal cord injury was implanted with two microelectrode arrays in area 1 of S1. Charge balanced, current controlled pulses evoked percepts spanning a range of qualities, from more naturalistic sensations such as touch and pressure to less naturalistic sensations such as tingle. To investigate the impact of stimulus parameters on

perceived intensity, we first tested stimulus trains with different fixed amplitudes and frequencies in a magnitude estimation task. Stimulation was delivered through individual electrodes and the participant was asked to report the perceived intensity on a self-selected scale. The relationship between current amplitude and perceived intensity was found to be linear. Changing frequency had more complex effects on perceived intensity that were electrode specific; on some electrodes, higher frequencies resulted in a higher perceived intensity, on others, lower frequencies resulted in a higher perceived intensity, and still on others, intermediate frequencies evoked the highest intensity. Cortical activity evolves spatiotemporally in response to mechanical inputs. Therefore, we next examined how biomimetic stimulus trains, with amplitudes and frequencies designed from neural recordings in S1 of monkeys, affected perceived naturalness. Trains with biomimetic amplitudes, frequencies, or both were compared to trains with fixed frequencies and amplitudes in a 2AFC task. The participant was asked to select the train that felt more natural. We found that biomimetic frequency modulation only occasionally increased naturalness and had electrode specific effects. On the other hand, biomimetic amplitude modulation increased naturalness across a variety of electrodes. Frequency modulation is a limited method to modulate naturalness and intensity because frequency effects are electrode specific. Amplitude modulation, however, can reliably encode signal intensity changes and can increase the naturalness of percepts evoked via biomimetic microstimulation.

Team & Individual Oral Abstracts

Thursday, April 25, 2019

08:00 – 10:00 Session 5, Panel III

Cerebellar computation 50 years after Marr-Albus: where are we now?

Terence Sanger¹, Mitsuo Kawato², Mackenzie Mathis³, Huu Hoang², Kazuo Kitamura⁴

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50 years later, the theory of cerebellar function proposed by Marr and Albus remains one of the most influential and debated computational models, driving the field of cerebellar study and providing an important example of the role of computational neuroscience. The original theory was based on the striking expansion from approximation 250 million mossy fibers to 50 billion granule cells, followed by compression through 15 million Purkinje cells eventually to fewer than 8 million cells in the deep cerebellar nuclei. In this workshop, we will revisit the Marr-Albus computational structure, and we will discuss this structure and its limitations in the context of more recent experimental and theoretical results. An important component of the discussion is to evaluate computational structure with respect to the motor function that it serves. We will show evidence that the cerebellum may have a very different function for eye movement, balance, reaching, and cognition despite its relative homogeneity of structure. The first two talks will address recent structural and functional experiments in mice. Kazuo Kitamura will discuss the role of climbing fiber signals during limb movements in mice using two-photon imaging. His results show that climbing fiber inputs to Purkinje cells correlate with different aspects of limb movement, indicating that population activity of climbing fibers encode details of the actual movements. Mackenzie Mathis will discuss the cerebellum in the context of sensorimotor cortical function and how these areas affect motor adaptation differentially in mice. For example, during a forelimb motor adaptation task, inactivation of the forelimb S1 affects learning but not control, while manipulation of Purkinje neurons causes both control and learning deficits, suggesting that cerebellum supports both motor learning and execution. The last two talks will address more recent computational

models of cerebellar function that expand upon the original functional mechanism proposed by Marr-Albus. Huu Hoang will address an important issue originally tackled by the Marr-Albus codon theory: how to reduce the degrees of freedom of a learning system in order to be able to learn from small samples. This work describes how neural synchronization dynamics can enable learning from a small training sample, and how the dynamics are actively controlled to adaptively change the degrees of freedom depending upon the stage of learning. Finally, Terry Sanger and Mitsuo Kawato will address the most extreme form of small-sample learning: one-shot learning. This was an original feature of the Marr-Albus model whose importance is often overlooked, and they will present a new analysis of the role of expansion recoding, in which the role of cerebellum is selective gating of sensory signals onto motor outputs to create stable dynamics for movement.

10:30 – 12:30 Session 6, Panel IV

New perspectives on the role of the superior colliculus in visually-guided motor behavior

Mayu Takahashi¹, John van Opstal², Neeraj Gandhi³, Ziad Hafed⁴

¹Tokyo Medical and Dental University, ²Radboud University Nijmegen, ³University of Pittsburgh, ⁴Tübingen University

The superior colliculus (SC) is a well-studied oculomotor control structure, containing an entire spectrum of significant contributions to, among others, visual sensation, gaze-shift commands, and all the way back to gaze-influenced visual modulations. This structure thus represents an ideal circuit model for investigating the remarkable robustness of visually-guided motor behavior in the brain. However, from the perspective of gaze control, the SC has often been reduced to a visual detection module in its superficial layers and a motor command module in its deeper layers. While generally true, such a model masks deeper questions about the nature and complexities of the computations performed by the SC. On the one hand, visual images in the real world are much richer than punctate spots of light often employed in the laboratory; on the other, each eye is manipulated by no less than 6 extra-ocular muscles requiring tight choreography to maintain well-known properties of eye movements like Listing's law. We have identified novel perspectives on SC function that push the limits of simplified textbook descriptions. The speakers will cover a journey from sensation to action. Hafed

will explore SC visual functions when viewed from the ecological perspective of making saccades in naturalistic scene settings. He will show that saccade motor control by the SC starts, in a sense, with the very first visually-induced spikes, whose properties are consistent with the SC being optimally tuned for natural scene statistics. Gandhi will then use simultaneous recordings to chart the time-course of sensorimotor transformation and additionally employ causal manipulations to highlight the importance of temporal dynamics in SC population activity in determining “when” to initiate a saccade. This will set the stage for van Opstal to assess how the SC computes “what” movement to produce. He will present evidence for a spike-by-spike control of instantaneous kinematics of head-unrestrained gaze shifts. Finally, Takahashi will broaden the gaze shifts studied in this session further by investigating how different ocular behaviors (e.g. voluntary saccades versus vestibular ocular reflexes) are ultimately coordinated by the time that motor neuron commands are compiled. She will use novel anatomical circuit techniques, combined with electrophysiology, to dissect the mechanisms of Listing’s law, explaining how a problem with 12 degrees of freedom (2 eyes x 6 extra-ocular muscles) is ultimately reduced to 2 degrees for voluntary saccades. We will end by discussing how future studies motivated by the current ones will explain SC roles beyond motor control, such as in the varied cognitive phenomena associated with active behavior.

15:00 – 17:00 Session 8, Panel V

Applications of deep learning in motor neuroscience

Chethan Pandarinath¹, Laura Driscoll², Alexander Mathis³, Nidhi Seethapathi⁴

¹Emory University and Georgia Institute of Technology,

²Stanford University, ³Harvard University, ⁴University of Pennsylvania

In recent years, deep artificial neural networks (ANNs) have revolutionized artificial intelligence and achieved state-of-the-art performance on many challenging machine learning problems. Due to their powerful computational architecture and the use of new training methodologies, ANNs can uncover meaningful representations from large, complex, and noisy datasets. Such datasets and challenges are increasingly common in motor neuroscience, due to the emergence of large-scale neural interfacing technologies and opportunities for monitoring complex behaviors, raising the possibility that

ANNs could broadly impact the field. This panel brings together four lines of research in which ANNs are solving previously intractable problems in motor neuroscience at a diversity of scales. We will present the use of ANNs to precisely model neuronal population dynamics in cortex, study how multiple cognitive tasks can be performed by the same network, perform pose estimation for precise quantification of animal behaviors, and facilitate automated movement classification and scoring in humans with potential applications to clinical diagnosis. Chethan Pandarinath will present the use of ANNs to uncover low-dimensional dynamics underlying neural population activity. He will show that, when applied to monkey motor cortical data, ANNs precisely estimate dynamics on single trials, yield accurate predictions of muscle activity, kinematics, and reaction times, infer perturbations to dynamics that correlate with behavior, and can combine data from multiple sessions (spanning months) to improve inference. Laura Driscoll will present an analysis of ANN models that were trained to perform multiple cognitive tasks. She will demonstrate how ANNs can be reverse engineered to develop an algorithmic understanding of multiple computations performed by a single dynamical system. Nidhi Seethapathi will present applications of ANNs for pose tracking and behavioral classification in humans. She will demonstrate pose tracking on in-the-wild videos to study fall predictions in the elderly, predict movement disorder risk in babies, and provide automatic feedback on exercise movements. She will also compare computer vision-based pose tracking to traditional motion capture for movement behavior tracking. Alexander Mathis will present work on behavioral analysis using markerless pose estimation, by leveraging fully convolutional ANNs and transfer learning to achieve excellent pose estimation performance with minimal training data. He will show results tracking various body parts in multiple species - from fruit flies to cheetahs in-the-wild - across a broad collection of behaviors. Finally, Andrew Pruszynski will help guide a stimulating panel discussion on challenges and opportunities in applying deep learning more broadly in motor neuroscience.

Team & Individual Oral Abstracts

Friday, April 26, 2019

08:00 – 10:00 Session 9, Individual II

Precise spike-timing codes for vocal motor control

Andrea Pack¹, Bryce Chung¹, Muneeb Zia², Coen Elemans³, Muhannad Bakir², Samuel Sober¹

¹Emory University, ²Georgia Institute of Technology, ³University of Southern Denmark

A central question in neuroscience is to establish how the brain controls muscle activity and modifies muscle output during motor skill learning. Early theories of brain function relied solely on spike rate (rate code), the total number of action potentials within a time interval, to explain sensory processing and motor control. Eventually, researchers studying sensory coding discovered that millisecond-scale spike timing patterns (timing-based codes) were far more informative about sensory inputs than were spike rates (Strong et al., 1998). Despite the strong evidence for timing codes in sensory systems, however, studies of the motor system have examined neuronal activity almost entirely in terms of spike rate. In theory, neurons can encode information via rate, timing, or a combination of the two. Because the information capacity of rate code is considerably smaller than that of a timing code, rate codes may be insufficient for transmitting information about the control of precise skilled motor behaviors. Previously, our lab discovered that neurons in a songbird's cortical vocal motor area (the robust nucleus of the arcopallium) encode significantly more information about upcoming vocal behavior by millisecond-scale spike timing patterns compared with spike rate (Tang et al., 2014). Although these results revealed that millisecond-scale differences in spike timing predict variations in behavior, we wanted to understand whether timing differences actually caused changes in motor output. To address this question, we recorded the activity of single motor units from expiratory muscles in songbirds during breathing behavior. Existing methods used to record electromyographic activity from muscles, such as surface and fine wire electrodes, typically cause injury at the implant site and are unable to record single motor unit activity from small, deep muscles. We therefore developed an innovative electrode system to record single motor unit activity from

multiple small (2 mm x 4 mm) muscles simultaneously and used information-theoretic analyses to identify the time scales, ranging from spike rate to millisecond timing, at which spike activity is most informative about predicting trial-by-trial variations in song acoustics. With these novel recording and computational techniques, we have established that millisecond-time scale spike timing patterns control respiratory muscles. Moreover, we found that experimentally-induced variation in spike timing patterns significantly alter muscle force output and breathing behavior (Srivastava et al., 2017). Ongoing studies investigate how spike timing-based codes in muscles change during skill learning by recording single motor unit activity from multiple vocal muscles during song learning and production. Together, our results suggest that learning a complex skill such as birdsong might depend on the nervous system's ability to organize precisely timed patterns of coordinated activity across neurons and motor units.

Motor variability predicts motor learning in complex real-world task

Shlomi Haar¹, Aldo Faisal¹

¹Imperial College London

Motor skill learning is a key feature of our development and our daily lives. Little is known about the behavioral and neural process of real-world motor skill learning, allegedly due to its complexity and the difficulty to measure and quantify it, in contrast to highly reductionistic controlled experiments. We demonstrate the feasibility of studying neuroscience in-the-wild: We use mobile brain and behavioral imaging to study real-world motor skill learning in a pool-table billiards paradigm. Billiards is a real-world task ideally suited to neurobehavioral study as motion tracking in terms of movement in space, the natural constraints of game play, and divisibility into trials, captures the style of reductionistic lab-based motor learning tasks. Naïve subjects, performed repeated trials where the cue ball and target ball were placed in the same locations, and subjects were asked to shoot the target ball towards the same pocket. During the entire learning process, we recorded the subjects' full body movements with a 'suit' of inertial measurement units, and their brain activity with wireless EEG. The balls on the pool table were tracked to assess the outcome of each trial. The learning curve in this real-life paradigm (over the directional error of the target ball) was similar to those

reported in the reductionistic error-based learning studies. Also, individuals with higher task-relevant motor variability (variability in the directional error of the target ball) over the first block of trials had faster learning in this complex real-world task, as found in controlled lab experiments (Wu et al. 2014). Studying in-the-wild learning enable looking at global observables of motor learning, as well as relating learning to mechanisms deduced from reductionist models. The analysis of the velocity profiles of all joints enabled in depth understanding of the structure of learning across the body. First, while most of the movement was done by the right arm, the entire body learned the task, as evident by the decrease in both inter- and intra- trial variabilities of various joints across the body over learning. Second, while over learning all subjects decreased their movement variability and the variability in the outcome (ball direction), subjects who were initially more variable were also more variable after learning, supporting the notion that movement variability is an individual trait (Haar et al. 2017). Lastly, when exploring the link between variability and learning over joints we found that only the variability in the right elbow supination shows significant correlation to learning. This demonstrates the relation between learning and variability: while learning leads to overall reduction in movement variability, only initial variability in specific task-relevant dimensions can facilitate faster learning. Crucially we are enabling novel hypothesis driven experimental approaches to study behavior where it matters most - in real life settings.

Motor expertise promotes transfer of visuo-motor compensations acquired during prism exposure

Lisa Fleury¹, Damien Pastor¹, Patrice Revol¹, Ludovic Delporte¹, Yves Rossetti¹

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The capacity to generalize motor transformations acquired in a specific context to new situations and the sensorimotor plasticity processes underlying this aptitude is a challenging topic in the field of motor control and has strong implications for rehabilitation. In this context, prism exposure is the most classic paradigm used to investigate the short-term plasticity set up to face perturbations. In the present study, we aimed at comparing the cross-transfer of visuo-motor compensations acquired during a 10° optical shift (prism exposure) between a throwing and a pointing task. In the first experiment, we recruited 24 healthy subjects randomly affected to two groups.

Participants in the throwing group were exposed to the prismatic deviation while performing throwing movements and were tested for transfer to the pointing task. Conversely, participants in the pointing group performed pointing movements during prism exposure and were tested for transfer to the throwing task. Error reduction during prism exposure and after-effects on the exposed task were similar in the two groups. However our results showed a unidirectional transfer of after-effects from pointing to throwing but not from throwing to pointing. We also noted that variability of movement accuracy was greater for throwing than for pointing. Thus, we speculated that the lower degree of expertise for throwing may explain this unidirectional transfer. In order to test for this hypothesis, we recruited 6 national- level dart players as throwing experts (experiment 2). They followed the same procedures as the previous throwing group. Crucially, throwing Experts were remarkably able to transfer compensations from throwing to pointing, suggesting that expertise in the exposed task has a marked influence in the capacity to generalize motor transformations to new situations. Finally, we explored the physiological mechanisms of transfer by investigating temporal dynamic of early compensations and kinematics of pointing movements (experiment 3). We recruited 20 novel healthy participants to constitute 2 other groups. They followed the same procedures except that we introduced early after-effects measures after the ten first trials of exposure. This experiment fully replicated experiment 1. In addition, after-effects were considerably less stable in the throwing group. Besides, kinematics allowed us to note that the throwing group showed some transfer from throwing to pointing only in the initial and intermediate phase of pointing trajectories but not during the terminal phase. This result suggests that expertise in a given motor task may be associated with changes in proprioceptive modality. To conclude, this study highlights the likely relationship between expertise and true adaptation that gives rise to transfer. These findings lead to a better understanding of the conditions needed to elicit context-independent transformations which might be crucial in neuro-rehabilitation of motor functions

Team & Individual Oral Abstracts

Friday, April 26, 2019

Global disinhibition as a key mechanism for the recovery of hand functions after spinal cord injury

Tadashi Isa¹, Reona Yamaguchi¹, Toshinari Kawasaki¹, Satoko Ueno¹, Masahiro Mitsuhashi¹, Zenas Chao¹

¹Kyoto University

Spinal cord injury (SCI) causes long-term devastating loss of physical functions in the patients, and therefore, elucidating the neuronal mechanism of recovery from SCI, which would contribute to development of better therapeutic strategies, is eagerly expected. We have previously shown that the activity of the ipsilesional motor cortex is enhanced and contribute to the hand movement control during the early recovery period in a partial spinal cord injury model of macaque monkeys (Nishimura et al. Science, 2007). More recently, we have found that the Granger causality from the contralesional premotor cortex to the ipsilesional premotor/primary motor cortices (PM/M1) is enhanced during that period (Chao et al. Cereb Cortex, 2018), which suggests the enhanced activity of the ipsilesional PM/M1 could be induced by the contralesional counterpart. To further understand the contribution of ipsilesional PM/M1 to recovery, we chronically implanted the multi-channel ECoG electrodes in the bilateral PM/M1/S1 and multiple EMG electrodes in the forelimb muscles in the macaque monkey. We longitudinally monitored the cortical and muscle activity during a reach and grasp task, and used direct electrical stimulation to probe the cortical connectivity before and after the sub-hemisection of the mid-cervical spinal cord (C4-C5). In this lesion model, the impairment of hand movements was more severe than the lateral funiculus-specific lesion model used in our previous studies. In the previous model, the precision grip mostly recovered in 1-3 months after the lesion, but in the current model, the recovery stopped at the coarse power grip and the precision grip did not fully recover. First, the results indicated that the high-gamma activity of the ipsilesional PM/M1 during the reach and grasp movements was enhanced after the lesion. The enhancement occurred first in the more rostral aspect of the PM but the locus gradually shifted caudally to the M1 as the recovery progressed. Along with the enhancement of the movement-related activity, the effect of a train

stimulation (at 3 mA, 3 shocks at 20 Hz) through each of the ECoG electrodes on the ipsilesional PM/M1 induced muscle twitches widely in digits, hand, wrist, elbow and shoulder of both the affected and unaffected forelimbs, back and even in bilateral hindlimb muscles which suggested disinhibition occurred widely in networks associated with the ipsilesional PM/M1. In addition, in the effected forelimb, the muscle twitch responses induced by stimulation of the ipsilesional PM/M1 could be enhanced by a conditioning stimulus given to the contralesional PM/M1. This suggested a facilitatory interaction between the bilateral PM/M1. All these results suggested that global disinhibition facilitated signal transmission from the contralesional PM/M1 to the ipsilesional PM/M1, which might have resulted in the enhanced movement-related activity of the ipsilesional PM/M1. Furthermore, disinhibition also occurred in the down

Dynamic sonomyographic imaging of the residual musculature provides proportional control for upper-extremity amputees

Wilsaan Joiner¹, Ananya Dhawan¹, Biswarup Mukherjee¹, Shriniwas Patwardhan¹, Nima Akhlaghi¹, Gyorgy Levay², Michelle Harris-Love¹, Siddhartha Sikdar¹

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Amputees often cite difficulty of use as a key contributing factor for abandoning their prosthesis, creating a pressing need for an improved control methodology. A major challenge of using traditional surface electromyography electrodes has been the difficulty in achieving intuitive and robust proportional control of multiple degrees of freedom. To address this problem, our group is refining a control method (sonomyographic control) that overcomes several limitations of myoelectric control. In sonomyography, muscle mechanical deformations are sensed using ultrasound, as compared to electrical activation, and therefore the resulting control signals can directly control the position of the end effector. Compared to myoelectric signals which control end-effector velocity, sonomyographic control is more congruent with the remaining proprioception within the residual limb. In addition, ultrasound imaging can non-invasively resolve individual muscles, including those deep inside the tissue, and detect dynamic activity within different functional compartments in real-time. This alignment between activation and proprioception, as well as the

ability to distinguish small, but significant differences in deep muscle tissue activations (e.g., different grasp patterns) may collectively provide more intuitive control signals for prosthetic devices. We tested our control method with 5 upper-extremity amputees (4 traumatic and 1 congenital) and 5 able-bodied subjects. In the task, dynamic ultrasound images measured contracting muscle deformations during actual motions of the limb, or approximated motions in the residuum (e.g., power grasp). This signal was used to move a screen cursor to a series of targets, and then hold the cursor at that location within a quantization bound. Performance metrics consisted of position error (the mean error between the cursor and the target position), stability error (the standard deviation of the cursor position from the target position), task completion rate and movement time. Both traumatic and congenital amputee subjects with no prior experience of using a sonomyography-based interface were able to demonstrate fine graded control of an end-effector controlled by muscle activation patterns in the remaining forearm. Specifically, position and stability errors for all subjects were below 3.5% and 12.1%, respectively. In addition, consistent with Fitts's law, movement time was significantly correlated and increased with task difficulty (i.e., the required movement distance) for all participants ($R > 0.85$). Finally, the average task completion rate was higher than 94% for the 11 graded target locations tested. Together, our results demonstrate the potential of using sonomyographic signals for intuitive dexterous control of multiarticulated prostheses. Beyond the control of prosthetic hands, sonomyographic signals may have potential clinical applications including fundamental investigations of motor control and biomechanics.

saccade preparation influences pupil size. Specifically, the pupil will constrict prior to an eye movement to a bright stimulus and dilate prior to an eye movement to a dark stimulus. Importantly, this modulation of pupil size occurs independent of global luminance levels. However, it remains to be determined which neural pathways produce this location specific modulation of pupil size. The intermediate layers of the midbrain superior colliculus (SCi) form part of the network of brain areas involved in both spatial attention and modulation of pupil size. In this study we manipulated SCi excitability via microstimulation or injection of lidocaine. Pupil size was altered according to local luminance level at the spatial location corresponding to a microstimulated location in the SCi map of monkeys. Moreover, local SCi inactivation through injection of lidocaine reversed this local luminance modulation. Our findings reveal a causal role of the SCi in preparing pupil size for local luminance conditions at the next saccadic goal. In conclusion, there is a part of the orienting circuit responsible for fine adjustments of pupil size independent of luminance and the SCi plays a key role in modulating this effect. Supported by CIHR.

Neural basis of location-specific pupil luminance modulation

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The pupil regulates the amount of light entering the eyes to optimize visual sensitivity and sharpness. The visual system selects objects of interest for future fixation, and pupil size can be adjusted for object luminance prior to fixation. Spatial attention enables us to focus visual processing towards specific locations or stimuli prior to the next fixation. Recent evidence has suggested that local luminance at the spatial locus of attention or

Team & Individual Oral Abstracts

Friday, April 26, 2019

10:30 – 12:30 Session 10, Panel VI

Multi-dimensional dexterous hand function and recovery

Jing Xu¹, Marco Santello², Firas Mawase³, Shinichi Furuya⁴

¹Johns Hopkins University, ²Arizona State University, ³Technion - Israel Institute of Technology, ⁴Sony Computer Science Laboratories Inc., Sophia University

Sensorimotor hand function spans a multidimensional space where biomechanical, neural, and cognitive factors interact to enable a rich repertoire of actions. Its complexity, with high dimensionality and variety of tasks, presents the major challenge in studying motor control and learning principles in manual skills. Traditionally, the synergy approach has been successful to study neural control of movement. How to use this approach in understanding control and learning principles in dexterous hand function is still facing various challenges. Moreover, dexterous hand function presents a large spectrum of manual capacity in different populations and expertise, and it can be the most challenging component to rehabilitate once injured. Here we present four different perspectives and approaches in tackling some of the most challenging issues. Marco Santello will focus on dexterous object manipulation and review insights obtained from research on control of the hand's multiple degrees of freedom, interaction between feedback and feedforward force control mechanisms, and neural constraints on learning and transfer of dexterous manipulation. This will be discussed in the context of clinical applications with emphasis on prosthetics and non-invasive neuromodulation. Jing Xu will present her work on independent control of fingers. She will first talk about the finding from a longitudinal stroke recovery study that separate biological systems support strength and individuation recovery. She will then present preliminary results from a new device and paradigm to capture independent movement at each finger joint in 3D, highlighting the superior independence of thumb and index finger, hallmark of the human hand dexterity. Firas Mawase will show how training on a novel motor skill might help improve finger dexterity in chronic stroke. He will present promising results on training stroke patients on

a chording task to break their abnormal flexion synergies at the chronic stage, especially improving movement quality, as opposed to task performance, that allows true generalization to motor hand functions. He will also discuss neural circuits that might underlie the improvement in dexterous hand function. Shinichi Furuya will present acquisition, degradation, and restoration of finger dexterity in musicians, covering three issues: neuromuscular adaptation underlying acquisition of finger dexterity, loss of it in focal dystonia, and its restoration through neuro-rehabilitation using motor retraining combined with tDCS. He will focus on changes through these three stages, highlighting neuromuscular attributes of individual differences in finger motor dexterity, to what extent the neural and anatomical characteristics accounts for differences in independent control of movements. Lastly, Marc Schieber will energize a 20-minutes discussion on challenges in studying dexterous hand function, possible universal principles across domains, and key factors in rehabilitation.

Saturday, April 27, 2019

08:00 – 10:00 Session 12, Panel VII

Beyond motor errors: New perspectives on the role of the cerebellum in learning

Richard Ivry¹, Court Hull², Mark Wagner³, Amanda Therrien⁴, Samuel McDougale⁵

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Computational theories of the cerebellum have focused on the idea that the anatomy and physiology of this subcortical structure is ideal for error-based learning. While this hypothesis has received substantial support in studies of simple motor behaviors (e.g., eye blink conditioning, sensorimotor adaptation), there are an increasing number of problematic findings. Physiological studies have identified situations in which climbing fiber activity, the putative source of error representation, is better characterized as signaling salient events or reward information, rather than errors. Other lines of evidence have linked cerebellar function to reward-based learning and more generally, to a role in decision making. These developments can be seen as part of a general paradigm shift in terms of our understanding of the functional

domain of the cerebellum. The goal of this workshop is to share these exciting new directions in cerebellar research with the NCM community. Four young investigators, using a range of physiological, computational, and behavioral methods, will present their work, asking how we need to rethink traditional perspectives on the role of the cerebellum in learning. Court Hull will present results from two different behavioral tasks in the mouse that suggest that climbing fiber activity can be seen as reporting and evaluating predicted task outcomes, rather than the classical conception that they signal motor errors. These results indicate that climbing fibers can provide predictive instructional signals that are not driven exclusively by motor errors. Mark Wagner is studying interactions between the frontal cortex and the cerebellum, using two-photon calcium imaging as mice learn a skilled, motivated behavior. Over the course of learning, initially dissimilar cortical and cerebellar ensembles become more correlated, with shared dynamics that extends over trial epochs from movement planning to reward processing. Skilled performance increases large-scale synchronization and task-locked complex spiking, suggesting a role in circuit coordination and timing, rather than error signaling. Amanda Therrien will report behavioral studies involving individuals with cerebellar degeneration. Her studies entail manipulations in which learning can be driven by either error signals or reward signals. The results indicate that reinforcement motor learning remains largely intact, but can be less efficient due to an increase in variability that cannot be estimated (or corrected for) by the motor system. Sam McDougle will discuss psychophysical results, asking about the interaction of different learning systems during motor learning. While this work has provided additional support for the role of the cerebellum in error-based learning, the results also point to a cerebellar contribution in other aspects of learning, including processes associated with higher level cognitive functions required for flexible action selection.

10:30 – 12:30 Session 13, Individual III

Encoding and control of motor prediction and feedback in the cerebellar cortex

Martha Streng¹, Laurentiu Popa¹, Timothy Ebner¹

¹University of Minnesota

Extensive research implicates the cerebellum as a forward internal model that predicts the sensory consequences

of motor commands and compares them to their actual feedback, generating prediction errors that guide motor learning. However, lacking is a characterization of how information relevant to motor control and sensory prediction error is processed by cerebellar neurons. Of major interest is the contribution of Purkinje cells, the primary output neurons of the cerebellar cortex, and their two activity modalities: simple and complex spike discharges. The dominant hypothesis is that complex spikes serve as the sole error signal in the cerebellar cortex. However, no current hypotheses fully explain or are completely consistent with the spectrum of previous experimental observations. To address these major issues, Purkinje cell activity was recorded during a pseudo-random manual tracking task requiring the continuous monitoring and correction for errors. The first hypothesis tested was whether climbing fiber discharge controls the information present in the simple spike firing. During tracking, complex spikes trigger robust and rapid changes in the simple spike modulation with limb kinematics and performance errors. Moreover, control of performance error information by climbing fiber discharge is followed by improved tracking performance, suggesting that it is highly important for optimizing behavior. A second hypothesis tested was whether climbing fiber discharge is evoked by errors in movement. Instead, complex spikes are modulated predictively with behavior. Additionally, complex spikes are not evoked as a result of a specific 'event' as has been previously suggested. Together, this suggests a novel function of complex spikes, in which climbing fibers continuously optimize the information in the simple spike firing in advance of changes in behavior. A third hypothesis tested is whether the simple spike discharge is responsible for encoding the sensory prediction errors crucial for online motor control. To address this, two novel manipulations of visual feedback during pseudo-random tracking were implemented to assess whether disrupting sensory information pertinent to motor error prediction and feedback modulates simple spike activity. During these manipulations, the simple spike modulation with behavior is consistent with the predictive and feedback components of sensory prediction error. Together, these results address a major outstanding question in the field of cerebellar physiology and develop a novel hypothesis about the interaction between the two activity modalities of Purkinje cells.

Team & Individual Oral Abstracts

Saturday, April 27, 2019

Spatial and temporal locomotor learning in the mouse cerebellum

Dana Darmohray¹, Jovin Jacobs¹, Hugo Marques¹, Megan Carey¹

¹Champalimaud Neuroscience Programme

Stable and efficient locomotion requires the precise coordination of movement across the limbs and body. Learned changes in interlimb coordination can be induced by exposure to a split-belt treadmill that imposes different speeds under each side of the body. Here we demonstrate locomotor learning on a split-belt treadmill in mice. Mouse locomotor adaptation is specific to measures of interlimb coordination, has spatial and temporal components that adapt at different rates, and is context-specific. The many similarities between human and mouse locomotor adaptation suggest that this form of locomotor learning is highly conserved across vertebrates. Using a variety of approaches, we demonstrate that split-belt adaptation in mice specifically depends on intermediate cerebellum, but is insensitive to large lesions of cerebral cortex. Finally, cell-type specific chemogenetics combined with quantitative behavioral analysis reveal that spatial and temporal components of locomotor adaptation are dissociable on the circuit level.

Implicit adaptation is driven by inverse model learning, not forward model learning

Alkis Hadjiosif¹, John Krakauer¹, Adrian Haith¹

¹Johns Hopkins University

It is widely thought that the implicit adaptation of motor commands in response to errors occurs through updating an internal forward model which predicts the consequences of motor commands, which in turn informs action selection. It has alternatively been suggested, however, that adaptation might occur by using errors to directly update an underlying controller - often referred to as an inverse model. Here we use a mirror reversal task to dissociate between these two options and find that, counter to prevailing views, implicit adaptation

is driven by inverse-model learning. The heart of the distinction between learning via forward and inverse models is that errors are known in sensory, not motor, coordinates. This is not a problem for forward model learning, since observed errors directly reflect errors in the forward model's output, enabling learning with no further assumptions. Thus, error can update the model under any imposed perturbation - be it a shifted visuomotor map (e.g. rotation), or a flipped one (e.g. mirror reversal). The inverse model's output, however, is in motor coordinates; thus, inverse model learning additionally needs to make an assumption about how changes in motor output relate to changes in sensory outcome - e.g. that leftward errors are reduced by shifting motor output rightward. This approach suffices for perturbations such as a rotation. Under mirror reversal, however, this approach fails: a rightwards adjustment to a leftwards error actually increases the error - the same update rules that normally enable adaptation to a rotation make the motor output drift further and further away from the target. We experimentally probed implicit adaptation under a mirror reversal to distinguish between these two types of learning. Participants (N=12) reached through 4 targets arranged along the cardinal directions. After baseline, we introduced a mirror reversal of the cursor across the y-axis. Participants were briefed on the perturbation and, to isolate implicit adaptation, were told to aim their hand, rather than the cursor, through the target - i.e. avoid any explicit re-aiming strategies, in spite of cursor errors. We found that participants consistently drifted away from the targets along the mirroring axis: small initial errors were amplified through implicit adaptation, consistent with our predictions for inverse-model-based learning, but not forward-model-based learning. Removal of visual feedback revealed clear aftereffects - the hallmark of implicit adaptation. This pattern was reproduced in two additional groups, one that allowed re-aiming, and another that tested implicit adaptation to targets in oblique directions relative to the mirroring axis. Thus, contrary to commonly accepted theories, implicit adaptation does not occur through updating a forward model but instead occurs through directly updating an inverse model. Further work will be needed to examine how updates to these two models interact during adaptation.

Somatosensory cortex participates in the consolidation of human motor memory

Neeraj Kumar¹, Timothy Manning², David Ostry³

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Behavioral studies have shown that newly learned motor skills are initially labile but are rapidly consolidated into a more stable state. The circuits which enable the consolidation of motor memories remain uncertain with most work to date focusing on primary motor cortex (M1). Here, by using transcranial magnetic stimulation (TMS) to block consolidation, we report the first direct evidence that plasticity in somatosensory cortex is involved in the consolidation of motor memory. The task involved force-field adaptation in which participants made movements to targets while a robot applied forces to the hand to alter somatosensory feedback. Immediately following adaptation, continuous theta-burst transcranial magnetic stimulation (cTBS) was delivered to block consolidation, then, following a 24-hour delay which would normally permit consolidation, we assessed whether there was an impairment in retention. It was found that when mechanical loads were introduced gradually to engage implicit learning processes, suppression of somatosensory cortex following training eliminated retention entirely. In contrast, cTBS to primary motor cortex following learning had no effect on retention at all; retention following cTBS to motor cortex was not different than following sham TMS stimulation. We confirmed that cTBS to somatosensory cortex blocked motor memory consolidation and that the observed loss of retention was not due to an inability to retrieve a consolidated motor memory. Specifically, retention was unaffected, which rules out a memory retrieval failure, when cTBS was delivered to somatosensory cortex after memory consolidation (24 hours after learning). In conclusion, somatosensory cortex rather than motor cortex is involved in the consolidation of motor memory.

Underlying mechanisms of reward-based motor learning

Peter Holland¹, Olivier Codol¹, Joseph Galea¹

¹University of Birmingham

The addition of rewarding feedback to motor learning tasks has been shown to increase the retention of learning, spurring interest in the possible utility for rehabilitation. However, the systems underlying this form of motor learning are poorly defined, especially in regards to the implicit or explicit nature of the learning. Initial investigations of reward-based feedback in motor learning demonstrated that small visuomotor rotations could be learnt. However, it remained unclear whether participants could compensate for larger rotations, and if learning occurred via explicit or implicit processes. To address this, subjects (n=30) made reaching movements towards a target with feedback restricted to a green tick when they successfully hit the target (reward-based feedback). Gradually the angle for a successful reach was rotated 25°. Only 66% of subjects showed successful reward-based motor learning. The remaining subjects initially followed the rotation but began to reach at an insufficient angle and returned to near baseline performance. Importantly, those that were successful accomplished this largely via explicit processes. Additionally, subjects who failed to learn showed decreased sensitivity to errors, a pattern previously found in Parkinsonian patients. In a second experiment, the addition of a secondary mental rotation task abolished learning (n=10), providing further evidence for the dependence on explicit mechanisms. Furthermore, disruption of learning by a dual-task was observed in a larger cohort (n=80) even when a closed-loop paradigm was employed. We sought to explain the large inter-individual variability by examining genetic and working memory-based predictors of performance. In a large (n=121) pre-registered experiment, we replicated the findings of the initial study, including the proportion of subjects who could not complete the task (26%). In contrast to decision-making literature, in which individual variations in dopaminergic genes predict various aspects of performance, we found no genetic predictors of reward-based motor learning. However, greater spatial working memory was predictive of improved motor learning. This was due to improved spatial working memory enabling participants to repeat rewarded actions more accurately.

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Also, this relationship held true for a second group of subjects (n=120) performing a related reward-based motor learning task. However, we found no predictors of individual's sensitivity to errors, another important driver of task success. Finally, using EEG to probe the neural response to errors during learning we found a highly reliable response in both ERPs and the theta frequency band (n=20). In summary, in a series of experiments employing reward-based feedback we provide strong evidence that a large component of this form of learning is under explicit control, is susceptible to disruption by dividing cognitive load, and individual aptitude is predicted by spatial working memory capacity.

Sleep's benefit on multiple forms of locomotor learning

Julia Choi¹, Rebecca Spencer¹, Gabriela Borin¹

¹*University of Massachusetts Amherst*

Sleep's benefit on motor learning has been demonstrated by greater performance changes over an interval with sleep (e.g., 8pm-8am) compared to an equivalent interval awake (8am-8pm). Off-line performance gains reflect memory consolidation, a process by which memories are strengthened and stabilized after the end of practice. However, sleep-dependent consolidation is not limited to the enhancement of memories exactly as it was learning; sleep also supports memory integration that is thought to underlie the generalization of skills. Here we tested the effects of sleep on transfer and relearning of complex locomotor skills. In the first experiment, we used a sequence learning task to determine whether transfer of locomotor learning involves memory integration processes that require time spent awake or asleep. Subjects practiced a sequence of step lengths based on visual cues in forward walking, and subsequently tested either with an untrained gait pattern (backward walking) using the same visual cues to probe transfer in the perceptual domain, or with the same gait pattern using different visual cues (inverted screen) to probe transfer in the motor domain. Transfer was assessed immediately (immediate transfer), and again 12-hr later (delayed transfer) following overnight sleep or daytime wake. We found minimal

immediate transfer in the perceptual domain; however, the backward pattern improved by about 10% following a 12-hr interval with sleep compared to only 1% following a 12-hr interval awake, suggesting that sleep plays a role in the delayed generalization of perceptual learning. Transfer in the motor domain improved to the same extent over 12-hr interval with sleep or awake, indicating that time-dependent processes underlie delayed generalization of motor learning. In the second experiment, we used a split-belt adaptation task to determine whether sleep accelerates relearning (i.e., savings) indicative of higher learning processes (i.e., learning to learn). Subjects performed split-belt treadmill walking at a 2:1 speed ratio, where spatial and temporal gait parameters were gradually recalibrated over 15 mins of training. Relearning of the 2:1 split-belt walking pattern was assessed immediately (immediate savings), and again 12-hr later (delayed savings) following sleep or wake. Subjects in the sleep group showed more delayed savings in step length symmetry compared to those in the wake group, demonstrating a benefit of sleep on spatial locomotor adaptation. Temporal locomotor adaptations did not show immediate savings, nor delayed savings after 12-hr interval with or without sleep. In sum, we showed that sleep-dependent consolidation of locomotor memories plays a role in the generalization of locomotor learning. The consolidation of complex locomotor skills entails parallel and distinct processes for motor and perceptual learning, as well as spatial and temporal control of gait, some of which preferentially or exclusively operates during sleep.

15:00 – 17:00 Session 15, Panel VIII

Complex material properties of muscle: artifacts or features?

Madhusudhan Venkadesan¹, Neville Hogan², Kiisa Nishikawa³, Lena Ting⁴

¹*Yale University*, ²*Massachusetts Institute of Technology*, ³*Northern Arizona University*, ⁴*Emory University & Georgia Tech*

The control of movement in animals relies on muscle's response to neural excitation and external perturbations. Are the complex mechanical properties of muscle relevant to motor control, or are they scientific curiosities that may be peripheral to controlling movement? Here we present four approaches, spanning length scales from the whole muscle to single proteins and timescales from minutes to milliseconds, to highlight how these complex material

properties of muscle may contribute to the the adept motor skills of animals.

Robots face many of the same challenges that animals face and an important one is of stably negotiating interactions with the environment. Impedance control is the mainstay of many robots today for controlling interactions and draws inspiration from muscle's tunable viscoelastic response. Hogan will discuss the variety of ways that muscle helps the motor control of movement and interaction, and elucidate the role of active muscle's viscoelasticity in these tasks. These results show the critical role played by the nervous system's ability to modulate the response of muscle to perturbations.

Depending on the neural drive, muscle behaves like a solid to stiffen a joint or fluid-like to undergo rapid stretch with little resistance. **Venkadesan** will analyze this apparent fluid-to-solid transition using theories based on A. Huxley's model of a sarcomere. This analysis of the collective dynamics of actomyosin crossbridges finds that the fluid-to-solid transition should be independent of the level of activation of the sarcomere, although that is not the case in animals. These results show a gap in our understanding of muscle as an active viscoelastic material.

Until recently, sarcomeric elements that are not part of the actomyosin apparatus were considered peripheral to its force production ability. However, the giant protein titin that tethers the thick and thin filaments is now recognized as playing an important role through its sensitivity to Ca^{2+} , i.e., to neural excitation. **Nishikawa** will discuss recent findings, based on studies from single molecule interactions to locomotor biomechanics and the response to sudden perturbations, on how titin may be involved in the viscoelastic response of the sarcomere and its fluid-to-solid transition.

Ting will discuss the functional role of muscle thixotropy in postural control and movement. Based on a two-state cross-bridge model and isolated skinned muscle fiber experiments her work demonstrates that the solid-to-fluid transition is dependent upon the Ca^{2+} concentration. Stretches in the range of normal postural sway maintain the short-range stiffness and elevated muscle spindle firing response that are both critical for reactive balance control. Stretches in the range of abnormal postural sway eliminate the short-range stiffness and the muscle spindle response, which reduce both the intrinsic, reflexive, and balance-correcting muscle forces needed to maintain balance.

17:00 – 18:00

Distinguished Career Award Talk

Evolving perspectives on the cortical control of reaching movements - Random observations and recollections from a reasonably OK career

John Francis Kalaska, *Université de Montréal*

Since the 1960s, neural recording studies of the cortical mechanisms of voluntary motor control have seen many technical and conceptual advances, from single-electrode recordings, restricted single-joint tasks and transcortical servo-control feedback loop models, to simultaneous multi-neuronal recordings, dimension-reduction algorithms, more naturalistic tasks and optimal-feedback and dynamical-network models. Through it all, the one constant has been the basic validity of the empirical data collected during experiments, irrespective of their initial motivation and interpretation. Those findings need to be reassessed but should not be dismissed. Rather than only dwelling on the past, I also plan to present new data showing that dorsal premotor (PMd) cortex neurons are implicated predominantly in the action-related aspects of a visual perceptual decision-making task before movement onset. After movement onset, the activity of many PMd neurons continues to reflect not only the chosen action but also the strength of evidence on which the decision was made and the associated likelihood of a successful outcome ("metacognition").

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Society for the
**Neural Control
of Movement**

30th NCM Annual Meeting

Valamar Lacroma
Dubrovnik Hotel
Dubrovnik, Croatia

April 27 – May 1, 2020

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Dubrovnik, Croatia is a UNESCO World Heritage protected city and is surrounded by 1,940 meters of unique medieval ramparts preserved in their original form. With a slogan of **Full.Of.Life**, the city of Dubrovnik has something for everyone from history to activities and abundant culture. An unrivalled scientific program matched with the beauty and diversity of Dubrovnik, makes for a meeting that shouldn't be missed.

Abstracts Open
October 16, 2019

Oral Submissions Close
November 18, 2019

Poster Submissions Close
February 24, 2020

Early Bird Registration
March 11, 2020

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Poster Sessions

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

SESSION 1

Wednesday April 24 08:00 - 17:30

Thursday April 25 08:00 - 17:30

Session 2

Friday April 26 08:00 - 15:00

Saturday April 27 08:00 - 15:00

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

Session - Theme - Board Number (Ex. 1-A-1)

THEMES

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

POSTER SESSION 1

Wednesday April, 24 & Thursday April 25

Posters are listed by theme.

All posters will be located on the 2nd Floor

A – Control of Eye & Head Movement

Poster Cluster (1-A-1 & 1-D-2)

1-A-1 Microsaccades in blindsight monkeys

Masatoshi Yoshida¹, Ziad Hafed²

¹National Institute for Physiological Sciences, ²Tübingen University

1-D-2 Exploring microsaccade-induced visual reafferent responses in macaque superior colliculus neurons

Fatemeh Khademi¹, Ziad Hafed², Chih-Yang Chen³

¹UKT, ²Tübingen University, ³Kyoto University

1-A-3 cTBS increases narrow-band gamma bursts and theta-band phase synchronization in the contralateral pre-frontal cortex in a primate model of rTMS

Brian Corneil¹, Thilo Womelsdorf², Sebastian Lehmann¹

¹Western University, ²Vanderbilt

1-A-4 Visual accuracy constraints do not influence saccade kinematics

Jeroen Goossens¹, Leslie Guadron¹

¹Donders Institute for Brain Cognition and Behaviour

1-A-5 Encoding and decoding strategies of natural self-motion in the vestibular pathway

Isabelle Mackrous¹, Jerome Carriot¹, Graham McAllister¹, Hammad Hooshangnejad², Kathleen Cullen², Maurice Chacron¹

¹McGill University, ²John Hopkins University

1-A-6 Spatiotemporal tuning of ocular following response can be acquired by statistical machine learning of visual images during daily self-movements

Daiki Nakamura¹, Hiroaki Gomi¹

¹NTT Communication Science Laboratories

1-A-7 Neural substrate for coordinated and uncoordinated pupil and saccade responses

Chin-An Wang¹, Doug Munoz²

¹Shuang Ho Hospital, Taipei Medical University, ²Queen's University

1-A-8 The effect of different visual conditions on gaze behaviors during a ball-catching task

Yusei Yoshimura¹, Keisuke Iwama¹, Tomohiro Kizuka¹, Seiji Ono¹

¹University of Tsukuba

B – Fundamentals of Motor Control

Poster Cluster (1-B-9 to 1-B-11)

1-B-9 Retinal eccentricity modulates visuomotor feedback gains along the movement

Justinas Cesonis¹, David Franklin¹

¹Technical University of Munich

1-B-10 Control of visually guided reaching: Can the sensorimotor control system independently modulate feedback from the hand and target?

David Franklin¹, Michael Dimitriou², Sae Franklin¹

¹Technical University of Munich, ²Umeå University

1-B-11 Visual error and internal model uncertainty contributes to visuomotor feedback gains

Sae Franklin¹, David Franklin¹

¹Technical University of Munich

1-B-12 Muscle activation strategy during fatigue

John Letizi¹, Joshua Kline¹, Gianluca De Luca¹, Paola Contessa¹

¹Delsys, Inc

1-B-13 Planter flexors activities during human upright standing are determined by cosine tuning

Kai Lon Fok¹, Daichi Nozaki², Kei Masani¹

¹University of Toronto, ²The University of Tokyo

1-B-14 Analysis of fixation points before and during writing a line

Ikuma Suwabe¹, Naohiro Fukumura¹

¹Toyohashi University of Technology

1-B-15 A stable, long-term cortical signature underlying consistent behavior

Juan Alvaro Gallego¹, Matthew Perich², Raeed Chowdhury³, Sara Solla³, Lee Miller³

¹Spanish National Research Council (CSIC), ²University of Geneva, ³Northwestern University

1-B-16 Proactive and reactive modulation of cortical excitation and inhibitory mechanisms during selective stopping of a planned bimanual action

Mark Hinder¹, Rohan Puri¹

¹University of Tasmania

1-B-17 Shocking discoveries: The effect of penalty modality on decision making and movement trajectories

Christopher Holland¹, Heather Neyedli¹

¹Dalhousie University

1-B-19 Bilateral motor synergies and interlimb force coordination in older adults

Hyun Joon Kim¹, Lisa Roberts², Clara Aziz³, Joon Ho Lee¹, Nyeonju Kang¹, Cauraugh James³

¹Incheon National University, ²University of Alabama, ³University of Florida

1-B-20 Enhancing motor sequence consolidation using anodal tDCS at primary motor cortex during a repetitive practice format

Taewon Kim¹, David Wright¹

¹Texas A&M University

1-B-21 Neuromuscular adaptation subserving independent control of finger movements in musicians

Yudai Kimoto¹, Takanori Oku², Shinichi Furuya²

¹Sophia University, ²Sony Computer Science Laboratories Inc. (Sony CSL)

1-B-22 Motor decision-making in the face of competing descending control

Victor Lobato-Rios¹, Pavan Ramdya¹

¹EPFL

1-B-23 Modulation of event-related spectral perturbations in the μ band during a position matching task: a study about neural correlates of upper limb position sense

Francesca Marini¹, Claudio Campus¹, Valentina Pippo¹, Pietro Morasso¹, Jacopo Zenzeri¹

¹Istituto Italiano di Tecnologia

1-B-24 Continuous neural and whole-body kinematic recordings across the rodent behavioral repertoire

Jesse Marshall¹, Tim Dunn², Diego Aldorondo¹, William Wang¹, Gordon Berman³, Bence Olveczky¹

¹Harvard University, ²Duke University, ³Emory University

1-B-25 Optimal force production via flexible neural control of motor units

Najja Marshall¹, Larry Abbott¹, Mark Churchland¹

¹Columbia University

1-B-26 Motor cortex mediates forelimb antagonist muscle cocontraction using a distinct control strategy

Claire Warriner¹, Samaher Fageiry¹, Shreya Saxena¹, Thomas Jessell¹, Rui Costa¹, Andrew Miri²

¹Columbia University, ²Northwestern University

1-B-27 Differential impact of interhemispheric inhibition on motor mirroring in the aged brain

Takuya Morishita¹, Jan Timmermann², Robert Schulz², Friedhelm Hummel¹

¹Swiss Federal Institute of Technology (EPFL), ²University Medical Center Hamburg-Eppendorf

1-B-28 Reticulospinal drive with a flexor bias can be detected as alpha-band shared neural drive during voluntary tasks in healthy individuals

Akira Nagamori¹, Christopher Laine¹, Francisco Valero-Cuevas¹

¹University of Southern California

1-B-29 Nerve-specific sensory attenuation during muscle contraction

Mayuko Radzikowski¹, Naotsugu Kaneko¹, Kimitaka Nakazawa¹

¹The University of Tokyo

1-B-30 Role of mesencephalic locomotor region in modulating locomotor modules in the lumbosacral spinal cord

Paola Salmas¹, Vincent C. K. Cheung¹

¹Chinese University of Hong Kong

1-B-31 Acute effect of blood flow restriction on muscle activation and force fluctuations during repetitive low load exercises

Yu-Han Su¹, Hsiu-Ju Tang¹, Ing-Shiou Hwang¹

¹National Cheng Kung University

1-B-32 Movement preparation time determines the precision of movement preparation

Katrin Sutter¹, Leonie Oostwoud Wijdenes¹, Robert van Beers¹, Pieter Medendorp²

¹Radboud University, ²Donders Institute, Radboud University

1-B-33 Characterizing age-related changes in supplementary motor area primary motor cortex connectivity

Ann-Maree Vallence¹, Brittany Rurak¹, Peter Drummond¹

¹Murdoch University

1-B-34 Remote activation of the ventral midbrain using tDCS of prefrontal cortex enhances online performance of a motor sequence skill

Yiyu Wang¹, Jessica Bernard¹, John Buchanan¹, David Wright¹

¹Texas A&M University

1-B-35 Spinal stretch reflexes support efficient reaching

Jeff Weiler¹, Paul Gribble¹, Andrew Pruszynski¹

¹Western University

1-B-36 Goal utility varies as a function of movement strategy

Aaron Wong¹, Audrey Green², Mitchell Isaacs¹

¹Moss Rehabilitation Research Institute, ²Holy Family University

1-B-37 Motor cortical control of muscle tone: evidence from the pelvic floor in humans

Moheb Yani¹, Jason Kutch¹

¹University of Southern California

1-B-38 Linear summation of spinally-induced forearm force field in macaque monkeys

Amit Yaron¹, Hiroaki Yaguchi¹, David Kowalski², Tomohiko Takei³, Kazuhiko Seki⁴

¹NCNP - National Center of Neurology and Psychiatry, ²Drexel University, ³Kyoto University, ⁴National Center of Neurology and Psychiatry

C – Posture & Gait

1-C-39 Postural control with the error feedback in the elderly

I-Ju Chen¹, Yi-Ying Tsai², Ing-Shiou Hwang²

¹National Cheng Kung University; Asia University, ²National Cheng Kung University

1-C-40 Stick balancing while standing: an example of dual unstable task control

Amel Cherif¹, Jacopo Zenzeri¹, Pietro Morasso¹

¹Istituto Italiano di Tecnologia

Poster Sessions

1-C-41 Difference in gait adaptability in stroke patients due to symmetry of foot contact position: split-belt treadmill adaptation behavior

Keisuke Hirata¹, Hiroki Hanawa¹, Taku Miyazawa², Keisuke Kubota¹, Moeka Sonoo¹, Takanori Kokubun¹, Naohiko Kanemura¹
¹Saitama Prefectural University, ²Hasuda Central Clinic

1-C-42 Are corrective muscle responses during a slip perturbation coordinated by the vestibular system?

Jonathan Lee¹, Christopher Asplund¹, Sarah Ruegg¹, Lauren Vera¹, Christopher Powers¹
¹University of Southern California

1-C-43 DeepLabCut: a tool for fast, robust, and efficient 3D pose estimation

Alexander Mathis¹, Tanmay Nath², Richard Warren³, An Chi Chen⁴, Amir Patel⁴, Venkatesh Murthy², Mackenzie Mathis², Matthias Bethge⁵
¹Harvard University / University of Tuebingen, ²Harvard University, ³Columbia University, ⁴University of Cape Town, ⁵University of Tuebingen

1-C-44 Long latency event-related desynchronization and synchronization of EEG beta-band in response to support-surface perturbations during quiet standing

Akihiro Nakamura¹, Yasuyuki Suzuki¹, Matija Milosevic¹, Taishin Nomura¹
¹Osaka University

1-C-45 Sensorimotor adaptation to alteration of postural dynamics induced by a closed-loop perturbation system

Daichi Nozaki¹, Shota Hagio¹, Anvar Azat¹, Yosuke Nakazawa¹
¹The University of Tokyo

1-C-46 To fall or not to fall: An initial passive phase that limits the time to recover and emphasizes the role of proprioceptive information

Maeva Le Goic¹, Danping Wang¹, Catherine Vidal¹, Elodie Chiarovano¹, Jennyfer Lecompte², Sebastien Laporte², Jacques Duysens³, Pierre-Paul Vidal¹
¹Paris Descartes University, ²Arts et Metiers ParisTech, ³KU Leuven

D – Integrative Control of Movement

1-D-47 Visual feedback processing during a rapid sensorimotor decision task

Deborah Barany¹, Margaret Schrayner¹, Ana Gomez¹, Tarkeshwar Singh²
¹University of Georgia, ²Medical University of South Carolina

1-D-48 Descending cortical pathways bidirectionally modulate forelimb tactile feedback in the cuneate nucleus

James Conner¹, Andrew Bohannon¹, Eiman Azim¹
¹Salk Institute for Biological Studies

1-D-49 Influence of visual and tactile object recognition on motor planning in non-human primates

Daniela Buchwald¹, Hans Scherberger¹
¹Deutsches Primatenzentrum GmbH

1-D-50 Spinal cord stimulation modulates the sensory cortex during passive leg movements

Radu Darie¹, David Borton¹
¹Brown University

1-D-51 Tactile information in the fingertips modulates upper limb responses during manipulation of a slipping object.

Carlos Hernandez-Castillo¹, Rodrigo Maeda¹, Andrew Pruszynski¹, Jorn Diedrichsen¹
¹Western University

1-D-52 The effect of augmented low-frequency error feedback on visuomotor tracking for the elders

Chia-Ling Hu¹, Ing-Shiou Hwang¹
¹National Cheng Kung University

1-D-53 Compensatory responses and reflex mechanisms in postural tongue control

Takayuki Ito¹, Andrew Szabados¹, Jean-Loup Caillet², Pascal Perrier³
¹GIPSA lab, ²CS System of Information, ³Grenoble-INP

1-D-54 Dynamic modulation of brain activities during three-ball cascade juggling

Hiroyuki Kambara¹, Makoto Miyakoshi², Hirokazu Tanaka³, Takahiro Kagawa⁴, Natsue Yoshimura¹, Yasuharu Koike¹, Scott Makeig²
¹Tokyo Institute of Technology, ²University of California, San Diego, ³Japan Advanced Institute of Science and Technology, ⁴Aichi Institute of Technology

1-D-56 Beta activity in SMA signals cognitive demand in motor control

Barbara Postigo Alonso¹, Marie Hofmann², Andrea Kühn², Wolf-Julian Neumann²
¹Universidad Loyola Andalucia, ²Charité - Universitätsmedizin Berlin

1-D-57 Trajectory deviation in the presence of distractors associated with positive and negative outcomes

Heather Neyedli¹, Alyssa Walsh¹, Kevin LeBlanc¹
¹Dalhousie University

1-D-58 Maintaining arm control during self-triggered unpredictable unloading perturbations

Sasha Reschektko¹, Anders Johansson², Andrew Pruszynski¹
¹University of Western Ontario, ²Umea University

1-D-59 Active perception through muscle synergies: A force perception study

Marco Santello¹, Simone Toma¹
¹Arizona State University

1-D-60 Spatial attention reflects sensorimotor decision making in situations of target uncertainty

Christian Seegelke¹, Tobias Heed¹
¹Bielefeld University

1-D-61 VTA is involved in both preparation and execution of motivated motor output

Sho Sugawara¹, Yoshihisa Nakayama², Yuki Hamano¹, Masaki Fukunaga¹, Tetsuya Yamamoto¹, Norihiro Sadato¹, Yukio Nishimura²
¹National Institute for Physiological Sciences, ²Tokyo Metropolitan Institute of Medical Science

E – Disorders of Motor Control

1-E-62 Insights from a brain computer interface user on intracortical control and feedback of robotic arms for object manipulation

Nathan Copeland¹, Kristin Quick, Robert Gaunt¹, Jennifer Collinger¹
¹University of Pittsburgh

1-E-63 Force matching in post-stroke fatigue

William De Doncker¹, Anna Kuppusswamy¹
¹University College London

1-E-65 Resting-state functional connectivity changes observed after five bouts of high-intensity cycling exercise paired with upper-limb motor practice in older adults

Brian Greeley¹, Jason Neva¹, Briana Chau¹, Christina Jones¹, Jennifer Ferris¹, Lara Boyd¹

¹University of British Columbia

1-E-66 Chronic stroke patients compensate loss of rotational joint work by increasing translational joint work during sit-to-stand motion

Hiroki Hanawa¹, Keisuke Hirata¹, Taku Miyazawa², Keisuke Kubota¹, Moeka Sonoo¹, Tsutomu Fujino¹, Takanori Kokubun¹, Naohiko Kanemura¹

¹Saitama Prefectural University, ²Hasuda Central Clinic

1-E-67 Transcranial direct current stimulation for walking capabilities in Parkinson's Disease: A Meta-Analysis

Rye Kyeong Kim¹, Hyo Keun Lee², Se Ji Ahn¹, Yang Mi Shin¹, Hyun Joon Kim¹, Joon Ho Lee¹, Kyoungkyu Jeon¹, Minchul Kim¹, Nyeonju Kang¹

¹Incheon National University, ²Vector Biomechanics Inc.

1-E-68 Motor unit control properties in neuromuscular disorders

John Letizi¹, Anant Shenoy², Gianluca De Luca¹, Serge Roy¹, Joshua Kline¹, Paola Contessa¹

¹Delsys Inc, ²Baystate Medical Center

1-E-69 ARCO: Cooperative arm rehabilitation after stroke

Miriam Schrafl-Altermatt¹, Felix Thomas¹, Michael Villiger¹

¹ETH Zurich

1-E-70 Sex and APOE genetics affect the relationship between dementia risk and cognitive-motor integration performance

Alica Rogojin¹, Diana Gorbet¹, Kara Hawkins¹, Lauren Sergio¹

¹York University

1-E-71 Visual feedback of object motion improves grip control but disrupts arm control in adults with ASC

Shinya Takamuku¹, Haruhisa Ohta², Chieko Kanai², Hiroaki Gomi¹

¹NTT Communication Science Laboratories, ²Showa university

F – Adaptation & Plasticity in Motor Control

Poster Cluster (1-F-72 to 1-F-74)

1-F-72 Mechanical transparency guides the selection of internal models

Carlo Campagnoli¹, Jordan Taylor¹

¹Princeton University

1-F-73 Sensory-prediction errors drive both motor adaptation and perceptual recalibration

Eugene Poh¹, Jordan Taylor¹

¹Princeton University

1-F-74 The long-term shortfalls of implicit sensorimotor adaptation

Sarah Hutter¹, Jordan Taylor¹

¹Princeton University

1-F-75 Multiple motor memories depending on foveal and peripheral reaching

Naotoshi Abekawa¹, Hiroaki Gomi¹

¹NTT Communication Science Laboratories

1-F-76 Neural correlates of sensorimotor adaptation in a spaceflight analogue environment

Lauren Banker¹, Jessica Lee², Nichole Gadd³, Igor Kofman⁴, Yiri De Dios⁵, Jacob Bloomberg³, Ajit Mulavara⁵, Rachael Seidler¹

¹University of Florida, ²Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), ³NASA Johnson Space Center, ⁴KBRyle, ⁵KBRwyle

1-F-77 Combining transcranial direct current stimulation and mirror therapy enhances upper limb motor control in chronic stroke survivors

Yen-Wei Chen¹, Yun Wang¹, Szu-Hung Lin¹, Ching-Yi Wu¹

¹Chang Gung University

1-F-78 Critical Periods After Stroke Study (CPASS): A Phase II Trial

Alexander Dromerick¹, Dorothy Edwards², Matthew Edwardson³, Margot Giannetti⁴, Jessica Barth⁵, Kathaleen Brady⁴, Abigail Mitchell⁴, Shashwati Geed⁴, Ming Tan³, Massimo Fiandaca⁶, Howard Federoff⁶, Elissa Newport³

¹MedStar National Rehabilitation Network and Georgetown University Medical Center, ²University of Wisconsin-Madison, ³Georgetown University Medical Center, ⁴MedStar National Rehabilitation Network, ⁵Washington University in St. Louis, ⁶University of California

1-F-79 The functional relevance of interhemispheric reorganization within the former sensory hand representation of unilateral amputees

Nathan Baune¹, Pin-Wei Chen¹, Benjamin Philip¹, Kenneth Valyear², Scott Frey³

¹Washington University, ²University of Bangor, ³University of Missouri

1-F-80 The motor engram as a dynamic change of the cortical network during early sequence learning: an fMRI study

Yuki Hamano¹, Sho Sugawara¹, Takaaki Yoshimoto¹, Norihiro Sadato¹

¹National Institute for Physiological Sciences

1-F-81 Movement velocity is more susceptible than duration to implicit motor adaptation for movement distance

Takuji Hayashi¹, Ken Takiyama¹

¹Tokyo University of Agriculture and Technology

1-F-82 Enhancing somatosensory perception of pianists by a novel haptic training

Masato Hirano¹, Mizuha Sakurada², Shinichi Furuya¹

¹Sony Computer Science Laboratories, Inc., ²Sophia University

1-F-83 Effect of a viewpoint on long-term retention of motor memory

Hiroshi Kadota¹, Satoru Sawada¹

¹Kochi University of Technology

1-F-84 Analyzing instrumental learning in blindsight monkeys with reinforcement learning model

Rikako Kato¹, Kei Majima¹, Akira Murakami¹, Abdelhafid Zeghib², Peter Redgrave², Yukiyasu Kamitani¹, Tadashi Isa¹

¹Kyoto University, ²Sheffield University

1-F-85 Peripersonal space and the experienced perturbation of a new force-field: story of a contraction

Nicolas Leclerc¹, Yann Coello², Fabrice Sarlegna³, Christophe Bourdin¹

¹Movement Sciences Institute of Marseille, ²Laboratoire de Sciences Cognitives et Affectives, ³Aix-Marseille University

1-F-87 Starting to dissociate explicit and implicit learning in studies of speech auditory-motor adaptation

Kwang Kim¹, Ludo Max¹

¹University of Washington

POSTER SESSION 2

Friday April 26 & Saturday April 27

Posters are listed by theme.

A – Control of Eye & Head Movement

2-A-1 Topographic representation of saccade vector in frontal eye field of common marmoset

Chih-Yang Chen¹, Denis Matrov¹, Kuan-Ting Ho¹, Tadashi Isa¹
¹Kyoto University

2-A-2 Neural mechanisms that allow cortical preparatory activity without inappropriate movement

Timothy Darlington¹, Stephen Lisberger¹
¹Duke University School of Medicine

2-A-3 Predicted tracking error triggers catch-up saccades during smooth pursuit

Omri Nachmani¹, Jonathan Coutinho¹, Aarlenne Khan², Phillip Lefèvre³, Gunnar Blohm¹
¹Queen's University, ²Université de Montréal, ³Université catholique de Louvain

2-A-4 Initial movement planning under uncertainty about task goal intends to prepare a desired state for the execution of possible secondary-movements

Ryoji Onagawa¹, Kazutoshi Kudo¹
¹The University of Tokyo

2-A-5 Identification of the frontal eye fields in the common marmoset using microstimulation

Janahan Selvanayagam¹, Lauren Schaeffer¹, Kevin Johnston¹, Stefan Everling¹
¹Western University

2-A-6 Does eccentric fixation alter head movement strategy for smooth pursuit?

Anca Velisar¹, Preeti Verghese¹, Natela Shanidze¹
¹The Smith-Kettlewell Eye Research Institute

2-A-7 A novel method to measure 3D eye movements with Infra-Red video eye tracking

Johan Pel¹, Patrick Forbes¹
¹ErasmusMC

2-A-8 Vestibulo-ocular response suppression during voluntary eye closure in man and monkey

Johannes van der Steen¹, Omid Zobeiri², Emma Raat¹, Jean-Sebastian Blouin³, Kathleen Cullen², Patrick Forbes¹
¹ErasmusMC, ²Johns Hopkins University, ³University of British Columbia

B – Fundamentals of Motor Control

Poster Cluster (2-B-9 & 2-B-10)

2-B-9 Learning compensation for different force fields and perturbation directions randomly applied during reaching

Frédéric Crevecoeur¹, Philippe Lefèvre¹, James Mathew¹
¹Université Catholique de Louvain,

2-B-10 Correlates of online changes in movement representations in 200ms

James Mathew¹, Marie Bastin¹, Philippe Lefèvre¹, Frédéric Crevecoeur¹
¹Université Catholique de Louvain

2-B-11 Surrounding inhibition in the internal globus pallidus at task-relevant frequency to facilitate motor control during a cyclic drawing task

Shinichi Amano¹, Enrique Argüelles¹, Ruta Deshpande¹, Diana Ferman¹, Terence Sanger¹
¹University of Southern California

2-B-12 Widespread activation in human GPi and motor thalamus positively correlates with muscle activation during voluntary movement

Enrique Argüelles¹, Shinichi Amano¹, Ruta Deshpande¹, Diana Ferman¹, Terence Sanger¹
¹University of Southern California

2-B-13 Robust control strategies in the presence of uncertain load environments

Joshua Cashaback¹, Ryan Miller¹, Michael Asmussen¹, Frédéric Crevecoeur², Tyler Cluff¹
¹University of Calgary, ²Université Catholique de Louvain

2-B-14 The effect of reward and punishment on upper limb motor control

Olivier Codol¹, Peter Holland¹, Joseph Galea¹
¹University of Birmingham

2-B-15 The inhibition of voluntary muscle relaxations depends on similar mechanisms to the inhibition of muscle contractions

Jack De Havas¹, Sho Ito¹, Hiroaki Gomi¹
¹NTT Communication Science Laboratories

2-B-16 Urgency tunes center-surround inhibition in the motor system during action selection

Gerard Derosiere¹, David Thura², Paul Cisek³, Julie Duque¹
¹Université Catholique de Louvain, ²Inserm U1028 - CNRS UMR 5292, ³Université de Montréal

2-B-17 A multi-domain task battery reveals functional boundaries in the human cerebellum

Jörn Diedrichsen¹, Carlos Hernandez-Castillo¹, Russell Poldrack², Richard Ivry³, Maedbh King³
¹Western University, ²Stanford University, ³University of California, Berkeley

2-B-18 Sensory context interferes with volitional modulation of single neurons

Carmen F Fisac¹, Steven Chase¹
¹Carnegie Mellon University

2-B-19 Errors in motor control correspond to increased mental workload during an object manipulation task

Kelene Fercho¹, Lee Baugh¹
¹University of South Dakota

2-B-20 Generalizability of a novel feedback controller is computationally demanding and sensitive to prior knowledge

Sarah Hutter¹, Samuel McDougale², Jordan Taylor¹
¹Princeton University, ²University of California, Berkeley

2-B-21 Spinal stimulus effects altered by voluntary muscle activity in monkeys

Miki Kaneshige¹, Kei Obara¹, Michiaki Suzuki², Toshiki Tazoe¹, Yukio Nishimura²
¹Neural Prosthesis Project, Tokyo Metropolitan Institute of Medical Science, ²Tokyo Metropolitan Institute of Medical Science

Poster Sessions

2-B-22 Mapping motor unit networks of human movement - Forwarding new possibilities

Joshua Kline¹, Paola Contessa¹, Bhawna Shiwani², John Chiodini², Serge Roy¹, Gianluca De Luca¹

¹Delsys, Inc, ²Delsys, Inc and Altec, inc

2-B-23 Action observation and execution differentially modulate basal ganglia-cortical activity in humans

Mahsa Malekmohammadi¹, Kathryn Cross¹, Jeongwoo Choi¹, Nader Pouratian¹

¹University of California, Los Angeles

2-B-24 Neural representations of rapid unlearning of force planning following object rotation

Michelle Marneweck¹, Scott Grafton¹

¹University of California Santa Barbara

2-B-25 The influence of preceding muscle activity on force perception in ballistic contractions

Takeshi Miyamoto¹, Tomohiro Kizuka¹, Seiji Ono¹

¹University of Tsukuba

2-B-26 Emergence of spinomuscular and corticomuscular loops in dynamic vs. static phases of precision grip

Tomomichi Oya¹, Tomohiko Takei², Kazuhiko Seki³

¹National Institute of Neuroscience, National Center of Neurology and Psychiatry, ²Kyoto University, ³National Center of Neurology and Psychiatry

2-B-27 Bimanual training results in M1 excitability changes, while delay interval length after training influences response time in a visual perception task but not motor skill consolidation

Inchon Park¹, John Buchanan², David Wright²

¹Korea Institute of Sports Science, ²Texas A&M University

2-B-28 Facilitatory effects of ipsilateral, contralateral and bilateral upper-limb muscle contractions on corticospinal and spinal reflex excitabilities in lower-limb muscles

Atsushi Sasaki¹, Naotsugu Kaneko¹, Yohei Masugi², Matija Milosevic², Kimitaka Nakazawa¹

¹The University of Tokyo, ²Tokyo International University, ³Osaka University

2-B-29 Cooperative hand movements up-regulate bilateral input to the upper limb - an ipsilateral MEP study

Miriam Schrafl-Altermatt¹, Harry Jordan², Kelly Ho², Winston Byblow²

¹ETH Zurich, ²University of Auckland

2-B-30 Macaque ventral midbrain facilitates the output to forelimb muscles via the primary motor cortex

Michiaki Suzuki¹, Ken-ichi Inoue², Hiroshi Nakagawa², Tadashi Isa³, Masahiko Takada², Yukio Nishimura¹

¹Tokyo Metropolitan Institute of Medical Science, ²Primate Research Institute, Kyoto University, ³Kyoto University

2-B-31 Planning of actions following predictive and non-predictive symbolic cues

Jennifer Swansburg¹, Heather Neyedli¹

¹Dalhousie University

2-B-32 Optimal motor decision-making through competition with opponents

Keiji Ota¹, Mamoru Tanaka², Kotaro Ishii², Ken Takiyama²

¹Tokyo University of Agriculture and Technology / New York University,

²Tokyo University of Agriculture and Technology

2-B-33 Volitional control of motor unit firing behavior for improved human-machine interface

Joshua Kline¹, Michael Twardowski², Serge Roy¹, Zhi Li³, Paola Contessa², Gianluca De Luca¹

¹Delsys, Inc, ²Delsys, Inc and Altec, Inc, ³Worcester Polytechnic Institute

2-B-34 Decoding muscle activity using electrocorticographic signals in freely behaving marmosets

Tatsuya Umeda¹, Masashi Koizumi², Yuko Katakai³, Ryoichi Saito², Kazuhiko Seki²

¹National Institute of Neuroscience, National Center of Neurology and Psychiatry, ²National Center of Neurology and Psychiatry, ³The Corporation for Production and Research of Laboratory Primates

2-B-35 Towards a neural population-level understanding of the effects of methylphenidate (Ritalin) in motor cortex of reaching monkeys

Jessica Verhein¹, Saurabh Vyas¹, Krishna Shenoy¹

¹Stanford University

2-B-36 Explaining the neural activity distribution associated with discrete movement sequences: Evidence for parallel functional systems

Willem Verwey¹, Peter Dominey², Jocelyne Ventre-Dominey²

¹University of Twente, ²INSERM U1093

2-B-37 Motor-cortical activity during bilateral and unilateral lower-limb force control

Akiko Yamaguchi¹, Atsushi Sasaki¹, Matija Milosevic², Kimitaka Nakazawa¹

¹The University of Tokyo, ²Osaka University

2-B-38 Interactions between short-latency afferent inhibition and cerebellar stimulation in the human motor cortex

Danny Spampinato¹, Giulia Dallera¹, John Rothwell¹

¹University College of London

C – Posture & Gait

2-C-39 Corticospinal excitability modulation during a precision locomotor task in humans

Charline Dambreville¹, Cécilia Neige¹, Catherine Mercier¹, Andréanne Blanchette¹, Laurent Bouyer¹

¹Center for Interdisciplinary Research in Rehabilitation and Social Integration

2-C-40 Association of cortical inhibition with gait and balance

Kathleen Hupfeld¹, Eric Porges¹, Chris Hass¹, Rachael Seidler¹

¹University of Florida

2-C-41 Facilitation of spinal reflexes in the lower-limb muscles during action observation combined with motor imagery of walking

Naotsugu Kaneko¹, Yohei Masugi², Noboru Usuda¹, Hikaru Yokoyama³, Kimitaka Nakazawa¹

¹The University of Tokyo, ²Tokyo International University, ³Tokyo University of Agriculture and Technology

2-C-42 Smaller perturbation-evoked cortical responses are associated with better balance ability in healthy young adults

Aiden Payne¹, Lena Ting¹

¹Georgia Tech/Emory University

2-C-43 Speed-accuracy tradeoff in anticipatory postural adjustment for a forward step

Masahiro Shinya¹

¹Hiroshima University

2-C-44 Sensor-based Characterization of gait impairments during activities of daily living

Joshua Kline¹, Bhawna Shiwani², Serge Roy¹, Paola Contessa¹, Marie Saint-Hilaire³, Christine Thomas³, Gianluca De Luca¹

¹Delsys, Inc, ²Delsys, Inc and Altec, Inc, ³Boston University

2-C-45 Changes in postural synergy due to mechanical knee constraint on an unsteady stance surface

YiYing Tsai¹, Ing-Shiou Hwang²

¹National Chung Kung University, ²National Cheng Kung University

2-C-46 Perceptive motor style at rest and during locomotion in humans

Danping Wang¹, Juan Mantilla¹, Jiuwen Cao², Jianzhong Wang², Laurent Oudre³, Pierre-Paul Vidal¹

¹Paris Descartes University, ²Hangzhou Dianzi University, ³University Paris 13

D – Integrative Control of Movement

2-D-47 Haptic and visual information about the to-be-grasped object is integrated in specific parts of the movement planning and execution phases

Ivan Camponogara¹, Robert Volcic¹

¹New York University Abu Dhabi

2-D-48 The reliability of the TMS-conditioned monosynaptic reflex in FCR muscle

Antonio Capozio¹, Samit Chakrabarty¹, Sarah Astill¹

¹University of Leeds

2-D-49 Simultaneous MEG and articulography for the study of speech motor control

Douglas Cheyne¹, Shaquille Nijjer¹, Cecilia Jobst¹, Fanny Hotze², David Meng³, Pascal Van Lieshout⁴, Teresa Cheung⁵, Blake Johnson³

¹Hospital for Sick Children Research Institute, ²Holland Bloorview Kids Rehabilitation Hospital, ³Macquarie University, ⁴University of Toronto, ⁵Simon Fraser University

2-D-50 Inter-individual variability and predictability of throwing actions

Antonella Maselli¹, Paolo Tommasino¹, Benedetta Cesqui², Marta Russo², Francesco Lacquaniti¹, Andrea d'Avella³

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

2-D-51 Representation of rotational and translational vestibular information in the human brain

Nobuhiro Hagura¹, Kazuma Aoyama², Hiroshi Ban³, Atsushi Yokoi³, Yuji Ikagaya², Hideyuki Ando⁴, Elisa Ferre⁵

¹University College London, ²University of Tokyo, ³National Institute of Information and Communications Technology, ⁴Osaka University, ⁵Royal Holloway University of London

2-D-52 Early developmental change in inter-muscle sensorimotor modules of human infants: Preliminary results

Hoshinori Kanazawa, Yasunori Yamada¹, Kazutoshi Tanaka¹, Masahiko Kawai², Yasuo Kuniyoshi¹

¹The University of Tokyo, ²The Kyoto University

2-D-53 Cortical local field potential control of epidural spinal stimulation for restoring forelimb movement after spinal cord injury

Abed Khorasani¹, Soshi Samejima¹, Nicholas Tolley¹, Adrien Boissenin¹, Chet Moritz¹

¹Rehabilitation Medicine, University of Washington

2-D-54 Invasive Brain-Computer Interface for avatar arm control in virtual reality using a deep learning decoder framework

Christian Klaes¹, Robin Lienkaemper¹, Muhammad Saif-ur-Rehman¹, Susanne Dyck¹, Ioannis Iossifidis²

¹Ruhr-University Bochum, ²University Ruhr West

2-D-55 A comparison of neuronal activity between the dorsal premotor area and the pre-supplementary motor area in primates during a two-movement sequence task

Toshi Nakajima¹, Ryosuke Hosaka², Hajime Mushiaki³

¹Asahikawa Medical University, ²Fukuoka University, ³Tohoku University

2-D-56 A communication subspace isolates population-level interactions between motor and somatosensory cortex

Matthew Perich¹, Sara Conti², Beatrice Barra², Marion Badi³, Sophie Wurth³, Melanie Kaeser², Jocelyne Bloch⁴, Grégoire Courtine³, Silvestro Micera³, Marco Capogrosso², Tomislav Milekovic¹

¹University of Geneva, ²University of Fribourg, ³École Polytechnique Fédérale de Lausanne, ⁴Centre hospitalier universitaire Vaudois

2-D-57 Towards understanding the role of task-related sensory information in motor cortex during object interaction

Marc Powell¹, David Borton¹

¹Brown University

2-D-58 Motor cortex is an input-dependent dynamical system controlling dexterous movement

Britton Sauerbrei¹, Jian-Zhong Guo¹, Matteo Mischiati¹, Wendy Guo¹, Mayank Kabra¹, Nakul Verma¹, Brett Mensh¹, Kristin Branson¹, Adam Hantman¹

¹Janelia Research Campus, HHMI

2-D-59 Is the manual following response an attempt to compensate for inferred self-motion?

Jeroen Smeets¹, Yajie Zhang¹, Jacques Duysens², Sabine Verschueren, Eli Brenner¹

¹VU University Amsterdam, ²KU Leuven

2-D-60 Exploring the limits of central pattern generators in quadruped locomotion using a musculoskeletal simulation model of mice

Shravan Tata Ramalingasetty¹, Grégoire Courtine¹, Auke Ijspeert¹

¹Ecole Polytechnic Federal Lausanne (EPFL)

2-D-61 Population dynamics in primary motor cortex during locomotion and obstacle avoidance

David Xing¹, Wilson Truccolo¹, David Borton¹

¹Brown University

2-D-62 The effect of individual traits on unintentional errors in skilled movement

Chiharu Yamada¹, Yoshihiro Itaguchi², Kazuyoshi Fukuzawa¹

¹Waseda University, ²Shizuoka University

Poster Sessions

2-D-105 Neurophysiological mechanism underlying cervical transcutaneous spinal cord stimulation in humans

Matija Milosevic¹, Yohei Masugi², Atsushi Sasaki³, Dimitry Sayenko⁴, Kimitaka Nakazawa³

¹Osaka University, ²Tokyo International University, ³The University of Tokyo, ⁴Houston Methodist Research Institute

E – Disorders of Motor Control

2-E-63 Patterns of Oculomotor Abnormalities in mild TBI

John Anderson¹

¹Minneapolis VA Health Care System - University of Minnesota

2-E-64 Changes in the relations between postural control, eye movements and cognitive involvement related to the effects of Parkinson's disease and age

Bonnet Cédric¹, Arnaud Delval², Tarkeshwar Singh³, Luc Defebvre²

¹SCALab UMR 9193, ²Unité INSERM 1171, Faculté de médecine, Université de Lille, ³Medical University of South Carolina

2-E-65 Multiple causes of pathological oscillations related to ataxia in mouse cerebellum

Guy Cheron¹, Axelle Leroy¹, Julian Cheron¹, Javiez Marquez², Laurence Ris³

¹Université Libre de Bruxelles, ²University Pablo de Olavide, ³University Mons

2-E-66 Pre-movement excitability in Post-Stroke Fatigue

William De Doncker¹, Anna Kuppaswamy¹

¹University College London

2-E-67 Optogenetically mediated neuromodulation of trunk motor cortex paired with exercised based rehabilitation leads to axial reflex changes below a complete T9/T10 spinal cord injury

Kendall Schmidt¹, Simon Giszter¹

¹Drexel University

2-E-68 Delays in reticulospinal system are correlated with deficits in motor learning in older adults

Joseph Schreiber¹, Sydney Schaefer¹, Claire Honeycutt¹

¹Arizona State University

2-E-69 Feedforward and feedback motor circuit dysfunction impairs reaching movements in EphA4 knockout mice

Juan Jiang¹, Bror Alstermark¹

¹Umeå University

2-E-70 Cortico-subcortical connectivity in stopping of ongoing movements

Roxanne Lofredi¹

¹Charité-Universitätsmedizin Berlin

2-E-72 Exploiting the Random Forest classification algorithm for identifying features of muscle synergy post-stroke

Lester K. P. So¹, Giacomo Severini², Catherine Adans-Dester³, Paolo Bonato³, Vincent C. K. Cheung¹

¹The Chinese University of Hong Kong, ²UCD Centre for Biomedical Engineering, ³Harvard Medical School

2-E-104 Elevated beta oscillatory brain activity during balance recovery in patients with Parkinson's disease

Nina Ghosn¹, Aiden Payne¹, Lena Ting¹

¹Georgia Tech/Emory University

F – Adaptation & Plasticity in Motor Control

2-F-73 Experienced prosthesis users exhibit accurate online error correction when reaching in the absence of visual feedback

Daniela Mattos¹, Carmen Cirstea¹, Scott Frey¹

¹University of Missouri

2-F-74 Challenging balance enhances generalization of visuomotor mappings across reaching and walking tasks

Amanda Bakkum¹, J. Maxwell Donelan¹, Daniel Marigold¹

¹Simon Fraser University

2-F-75 The complexity of tapping force and vertical displacement in finger tapping is higher for individuals who show repeated bout rate enhancement than for those who do not

Anders Emanuelsen¹, Pascal Madeleine¹, Michael Voigt¹, Ernst Hansen¹

¹Aalborg University

2-F-76 Contralateral transfer of repeated bout rate enhancement in rhythmic movement

Ernst Hansen¹, Søren Bak¹, Lasse Knudsen¹, Bo Seiferheld¹, Andrew Stevenson¹, Anders Emanuelsen¹

¹Aalborg University

2-F-78 The proficiency and strategy in tool-use grasping

Yoshihiro Itaguchi¹

¹Shizuoka University

2-F-80 Concurrent visuomotor and dynamic perturbations of one hand increase contralateral interference in a bimanual task

Florian Kagerer¹, Phillip Desrochers¹, Kayley Irwin¹, Alexander Brunfeldt¹

¹Michigan State University

2-F-81 Effects of volitional preemptive abdominal contraction strategies on co-activation of lumbar multifidus under different postures

Chieh-Yu Kao¹, Yi-Liang Kuo¹, Kai-Chia Cheng¹, He-Xin Zheng¹, Yi-Ju Tsai¹

¹National Cheng Kung University

2-F-82 Looking for a sign of failure in actions: Reaching Errors triggered by slowing down of movement and specific brain activity in preceding trials

Toshiki Kobayashi¹, Mitsuki Takemi¹, Daichi Nozaki¹

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2-F-83 Mechanistic determinants of interlimb transfer of visuomotor learning

Adarsh Kumar¹, Pratik Mutha¹

¹IIT Gandhinagar, India

2-F-84 Reinforcement schedules to modify movement coordination in redundant motor tasks

Tzu-Hsiang Lin¹, Rajiv Ranganathan¹

¹Michigan State University

2-F-85 Changes in resting-state functional connectivity and behavior associated with a spaceflight analogue environment

Heather McGregor¹, Jessica Lee², Nichole Gadd³, Igor Kofman⁴, Yiri De Dios⁵, Jacob Bloomberg³, Ajit Mulavara⁵, Rachael Seidler¹

¹University of Florida, ²Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), ³NASA Johnson Space Center, ⁴KBRyle, ⁵KBRwyle

2-F-86 Unique excitation of the ipsilateral motor pathway in an elite high jumper with below-knee amputation

Tomoya Nakanishi¹, Atsushi Sasaki¹, Kento Nakagawa², Kimitaka Nakazawa¹

¹The University of Tokyo, ²Toronto Rehabilitation Institute

2-F-87 EEG correlates of effort and reward processing during reinforcement learning.

Dimitrios Palidis¹, Paul Gribble¹

¹University of Western Ontario

2-F-88 Does motor variability predict individual differences in learning a redundant skill-learning task?

Rajiv Ranganathan¹, Marco Lin¹, Samuel Carey¹, Rakshith Lokesh¹, Mei-Hua Lee¹, Chandramouli Krishnan¹

¹Michigan State University

2-F-89 Individual optimal attentional strategy dependent social interaction during a dyadic motor learning task

Takeshi Sakurada¹, Aya Goto², Shin-ichiro Yamamoto²

¹Ritsumeikan University, ²Shibaura Institute of Technology

2-F-90 Exploration of distinct neural activity repertoire during learning of new arm dynamics

Xulu Sun¹, Daniel O'Shea¹, Eric Trautmann¹, Matthew Golub¹, Saurabh Vyas¹, Tucker Fisher¹, Stephen Ryu², Krishna Shenoy¹

¹Stanford University, ²Palo Alto Medical Foundation

2-F-91 Variable brain states practice improves the retention of motor memory

Mitsuaki Takemi¹, Toyo Ogasawara, Hartwig Siebner², Daichi Nozaki¹

¹The University of Tokyo, ²Copenhagen University Hospital Hvidovre

2-F-92 Interlimb transfer of sensorimotor adaptation may not reflect interhemispheric transfer: New insights from patients with corpus callosum abnormalities

Penelope Tilsley¹, Patricia Romaiguère¹, Eve Tramoni¹, Olivier Felician¹, Fabrice Sarlegna¹

¹Aix-Marseille University

2-F-93 Broadband masking noise contributes to speech motor control under formant transformed auditory feedback

Yasufumi Uezu¹, Sadao Hiroya¹, Takemi Mochida¹

¹NTT Communication Science Laboratories

2-F-94 Climbing fiber synchronization emerges with skilled movement acquisition

Mark Wagner¹, Gabriel Mel¹, Joan Savall¹, Oscar Hernandez¹, Hakan Inan¹, Oleg Rumyantsev¹, Tony Kim¹, Surya Ganguli¹, Liqun Luo¹, Mark Schnitzer¹

¹Stanford University

2-F-95 Pupil-linked arousal modulates trial-by-trial adaptation during reaching

Atsushi Yokoi¹

¹National Institute of Information and Communications Technology

2-G-97 Rotational neural population dynamics in motor cortex are differentially prevalent during reaching and grasping movements

James Goodman¹, Aneesha Suresh¹, Elizaveta Okorokova¹, Alex Lee¹, Nicholas Hatsopoulos¹, Sliman Bensmaia¹

¹University of Chicago

2-G-98 A revised computational neuroanatomy for motor control

Shlomi Haar¹, Opher Donchin²

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

2-G-99 Development of anatomically correct musculoskeletal model based on MRI images

Masaya Hirashima¹, Takuya Sonoda², Shoji Konda²

¹Center for Information and Neural Networks, National Institute of Information and Communications Tec, ²Osaka University

2-G-100 Transient behavior and predictability in manipulating complex objects

Rashida Nayeem¹, Salah Bazzi¹, Kaleb Noruzi¹, Neville Hogan², Dagmar Sternad¹

¹Northeastern University, ²Massachusetts Institute of Technology

2-G-101 Discovering preference in human locomotion with robust inverse optimal control

John Rebula¹, Stefan Schaal², Nicolas Schweighofer³, James Finley³, Ludovic Righetti⁴

¹Max Planck Institute for Intelligent Systems, ²Google X, ³University of Southern California, ⁴New York University

2-G-102 Learning of generative neural networks models for EMG data constrained by cortical activation dynamics

Alessandro Salatiello¹, Martin Giese¹

¹University of Tübingen

2-G-103 A model of speed-accuracy trade-offs based on human arm dynamics

Misaki Takeda¹, Isao Nambu¹, Yasuhiro Wada¹

¹Nagaoka University of Technology

NOTES

G – Theoretical & Computational Motor Control

2-G-96 Saccade vigor reflects utility in effort-based decisions

Alaa Ahmed¹, Daniel Apuan¹, Colin Korbisch¹

¹University of Colorado Boulder

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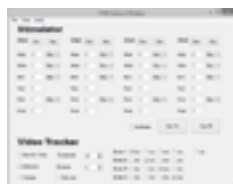
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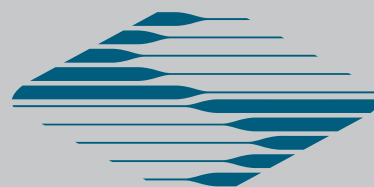
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Raina D'Aleo

Johns Hopkins University

Raina D'Aleo is a Neuroscience Ph.D Candidate in the Lab of Sridevi Sarma at Johns Hopkins School of Medicine. She received her B.S. in Physics and Astronomy at the University of Washington in 2014 but transitioned to the biological sciences after becoming a Research Associate in the Neural Coding Department at the Allen Institute for Brain Science. Now at the intersection of modeling complex systems and investigating neural responses, Raina's current research collaborates with Marc Schieber's group at the University of Rochester to investigate how motor cortices dynamically interact throughout movement, utilizing dynamical systems theory.



Brian Dekleva

University of Pittsburgh

Brian Dekleva received his PhD in Biomedical Engineering from Northwestern University, where he focused on movement planning in motor and premotor cortex in the face of uncertainty. His current work uses brain-computer interfaces to address basic scientific questions about how motor cortex behaves when interacting with objects.



Alkis Hadjiosif

Johns Hopkins University

I earned my PhD from Harvard University under Prof. Maurice Smith, and I am currently a postdoctoral researcher in Johns Hopkins with Prof. John Krakauer. My research aims to understand the mechanisms of motor control and motor learning, and how these mechanisms are specifically affected in neurological disease, especially stroke.



Peter Holland

University of Birmingham

Peter Holland is a postdoctoral research fellow in Joseph Galea's group at the University of Birmingham. Having previously investigated the electrophysiology of the basal ganglia (University of Oxford) and cerebellum (Erasmus MC/Ben Gurion University) he currently researches the different systems that mediate reward-based motor learning.



Christopher Hughes

University of Pittsburgh

I am a third-year pre-doctoral student at the University of Pittsburgh working with Dr. Robert Gaunt. We work with a spinal cord injured human participant implanted with Utah arrays in motor and somatosensory cortex for control of a bidirectional prosthesis. I primarily study how stimulus parameters modulate tactile perception.



Rodrigo Maeda

Western University

Rodrigo S Maeda is a PhD Candidate in the lab of Dr. Andrew Pruszynski at the University of Western Ontario. His research focuses on investigating the shared neural circuits that underlie the feedforward and feedback control of reaching in humans and monkeys.



Alexander Mathis

Harvard University/University of Tuebingen

Alexander Mathis studies adaptive motor control, the senses of touch and smell as well as deep learning methods for video analysis. He did his PhD in the group of Prof. Andreas V.M. Herz in Munich and worked on deriving tuning properties of grid cells from first principles.



Martha Streng

University of Minnesota

I received my PhD in Neuroscience from the University of Minnesota Dr. Timothy Ebner's lab, where I studied Purkinje cell and climbing fiber activity during online motor control tasks. I am currently a postdoctoral researcher in the lab of Dr. Esther Krook-Magnuson working on cerebellar neuromodulation in epilepsy.



Samuel McDougale

University of California, Berkeley

After earning a Bachelor's degree in Neuroscience and Behavior from Vassar College in 2009, Sam spent two years as a research assistant with Professor Javier Medina studying how computations in the cerebellum can lead to well-timed, coordinated movements. Sam began a PhD in Psychology & Neuroscience at Princeton University in 2013, where he was an NSF Graduate Research Fellow. At Princeton, Sam worked with Professors Jordan Taylor and Yael Niv, and collaborated with Professor Richard Ivry (UC Berkeley). Sam's research concerns measuring and modeling human motor and reinforcement learning and mapping different learning systems to their respective neural substrates, using psychophysics, computational models, neuropsychology, and fMRI. He earned his PhD in 2018, and is currently a postdoc at UC Berkeley with Professors Anne Collins and Richard Ivry.



Amanda Therrien

Johns Hopkins

Amanda obtained her BSc in Human Kinetics from the University of Ottawa in 2008. She then obtained her PhD in Kinesiology specializing in Sensorimotor Neuroscience from McMaster University in 2013. Since then she been a postdoctoral fellow at the Kennedy Krieger Institute and Johns Hopkins School of Medicine.



Mark Wagner

Stanford University

Mark Wagner is postdoctoral researcher with Dr. Liqun Luo at Stanford University. Mark is investigating the interactions between the neocortex and the cerebellum that underlie skill learning. Mark obtained his Ph.D. with Dr. Mark Schnitzer at Stanford, and his B.A. and M.S. with Dr. Maurice Smith at Harvard University.



Andrea Pack

Emory University

Andrea Pack is an NSF graduate fellow in Neuroscience at Emory University. She is currently studying the neurobiology of motor control and sensorimotor learning in Dr. Samuel Sober's lab. Her thesis research focuses on the development of activity patterns within and across vocal muscles during motor skill learning in songbirds.



Poster Room Floor Plans

Session #1

Wednesday April 24 08:00 - 17:30

Thursday April 25 08:00 - 17:30



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THEMES

A - Control of Eye & Head Movement

B - Fundamentals of Motor Control

C - Posture and Gait

D - Integrative Control of Movement

E - Disorders of Motor Control

F - Adaptation & Plasticity in Motor Control

G - Theoretical & Computational Motor Control

Session #2

Friday April 26 08:00 - 15:00

Saturday April 27 08:00 - 15:00



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