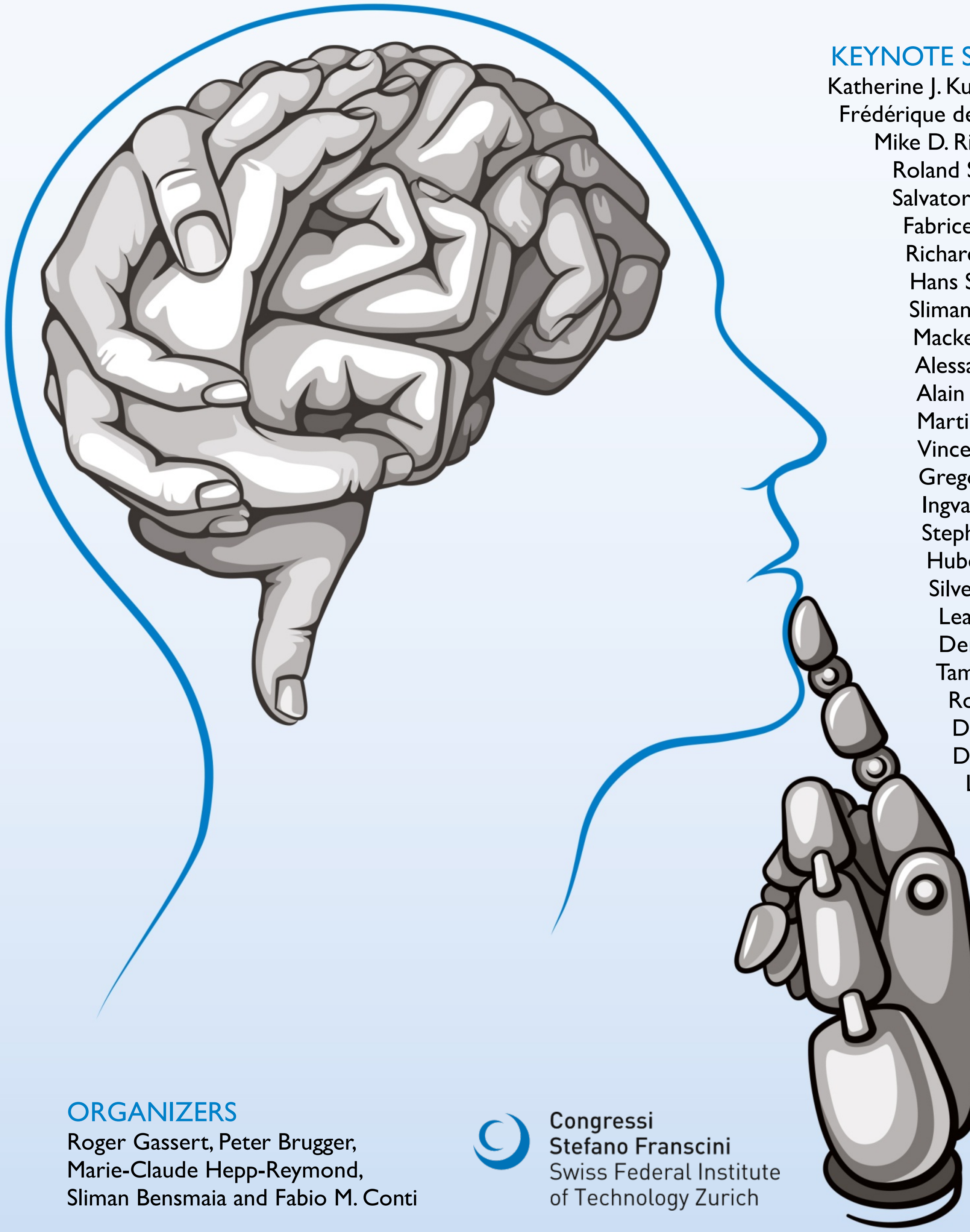
HAND, BRAIN & TECHNOLOGY

THE SOMATOSENSORY SYSTEM

Monte Verità, Ascona, Switzerland, August 26 – 31, 2018



KEYNOTE SPEAKERS

Katherine J. Kuchenbecker
Frédérique de Vignemont
Mike D. Rinderknecht
Roland S. Johansson
Salvatore M. Aglioti
Fabrice R. Sarlegna
Richard Andersen
Hans Scherberger
Sliman J. Bensmaia
Mackenzie Mathis
Alessandro Farnè
Alain Kaelin-Lang
Martin H. Fischer
Vincent Hayward
Gregory A. Clark
Ingvars Birznieks
Stephen H. Scott
Hubert R. Dinse
Silvestro Micera
Leah Krubitzer
Derek Kamper
Tamar R. Makin
Robert Gaunt
Dustin J. Tyler
Daniel Huber
Lee E. Miller
Aldo Faisal

ORGANIZERS

Roger Gassert, Peter Brugger,
Marie-Claude Hepp-Reymond,
Sliman Bensmaia and Fabio M. Conti

Congressi
Stefano Franscini
Swiss Federal Institute
of Technology Zurich

WELCOME

Dear Attendees

A warm welcome to the "Hand, Brain and Technology: The Somatosensory System" Conference on Monte Verità, held within the Congressi Stefano Franscini (CSF) conference series! The tight functional coupling between hand and brain has greatly shaped the evolution of language, culture and technology. Any reduction or loss of hand function, whether of central or peripheral origin, has devastating effects on the independence and social integration of the affected person. And any treatment, be it through human or technological intervention, must account for this unique coupling. As a result, hand and brain have drawn strong interest from the social, medical and engineering sciences alike. In this second incarnation of the "Hand, Brain, and Technology" conference, we focus on the somatosensory aspect of hand function, its neural basis and its role in abstract cognition and emotion. We also feature efforts to restore somatosensation in various clinical contexts, including amputation, spinal cord injury, and stroke.

This is the fourth CSF conference on these topics, following two successful events organized by Mario Wiesendanger in 1994 (Sensorimotor Function of the Hand: Mechanics and Control) and 1998 in collaboration with Marie-Claude Hepp-Reymond (Neural Basis of Hand Dexterity), the former of which resulted in a book entitled "Hand and Brain – The Neurophysiology and Psychology of Hand Movements", which has become classical reading in the field. In 2014, we complemented the previous two meetings with an engineering component, with the aim of promoting interaction and collaboration across disciplines. The present meeting builds directly on that of 2014, but with a focus on the importance of the somatosensory system.

Aligned with the philosophy of CSF conferences, there will be ample time for discussions, as well as for junior and advanced researchers to disseminate their work and interact extensively with senior researchers. We thank you all for coming, and for contributing to this unique event with your interest and presentations. We also thank our many sponsors, the CSF and our two partner clinics for making this event possible, and wish you an intellectually stimulating and inspiring week on the Monte Verità!

Sincerely,

The organizers

Prof. Roger Gassert
Rehabilitation engineering
Department of Health Sciences
and Technology, ETH Zurich

Prof. Peter Brugger
Neuropsychology
Department of Neurology
University Hospital Zurich

Prof. Marie-Claude Hepp-Reymond
Neural control of grasping
Institute of Neuroinformatics
ETH Zurich and University of Zurich

Prof. Sliman Bensmaia
Somatosensory neuroscience and
neuroprosthetics
University of Chicago

Dr. med. Fabio Mario Conti
Neurocognitive rehabilitation
Clinica Hildebrand Centro
di riabilitazione Brissago

PARTNERS AND SPONSORS

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Congressi
Stefano Franscini
Swiss Federal Institute
of Technology Zurich

CLINICAL/SCIENTIFIC PARTNERS

CLINICA HILDEBRAND
Centro di riabilitazione Brissago

rehaklinik
bellikon
Unfall- und Sportreha

SPONSORS

FNSNF
FONDS NATIONAL SUISSE
SCHWEIZERISCHER NATIONALFONDS
FONDO NAZIONALE SVIZZERO
SWISS NATIONAL SCIENCE FOUNDATION

eoc
Ente Ospedaliero Cantonale

Boehringer Ingelheim
Stiftung

BLACKROCK®
MICROSYSTEMS

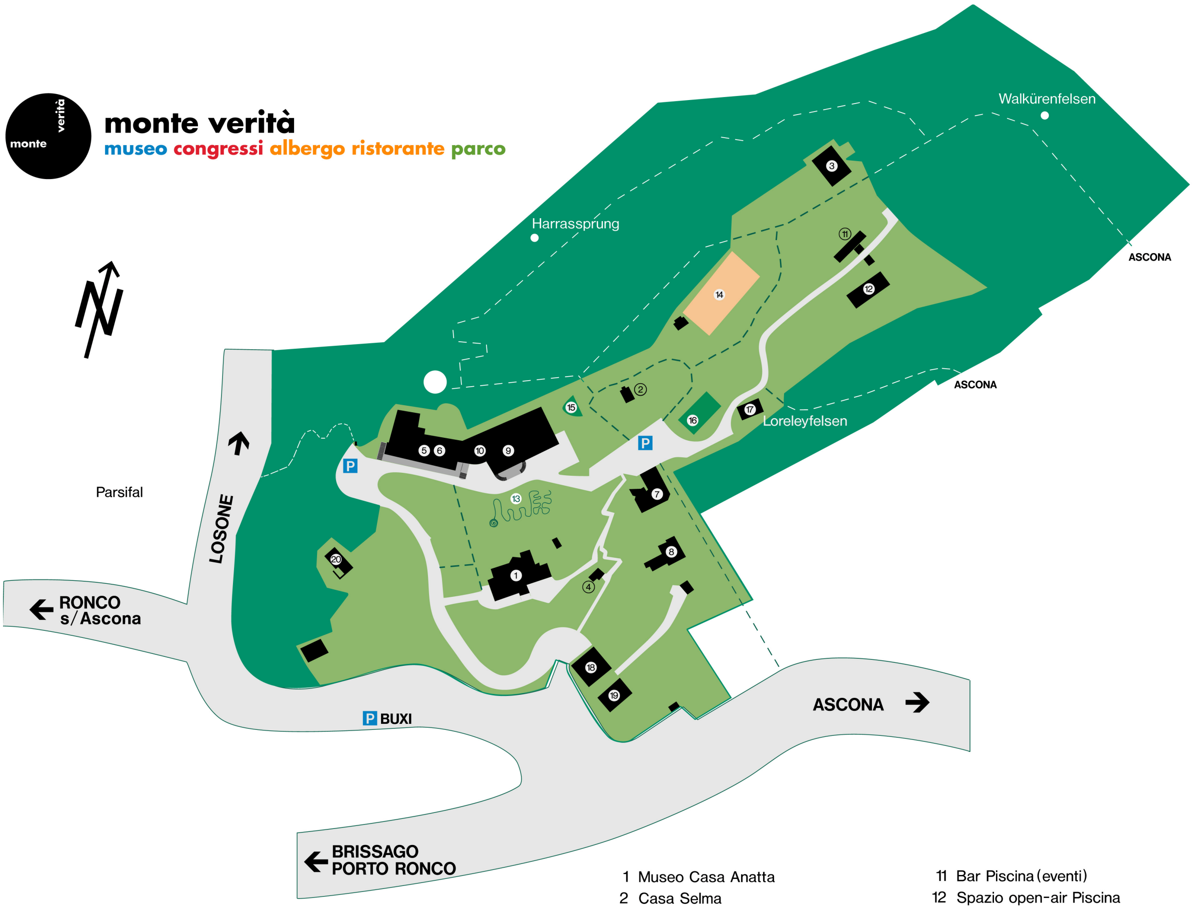
Fondazione
Neuroscienze
Ticino

satw
it's all about
technology

RELAB
REHABILITATION ENGINEERING LAB

VENUE

The CSF (Congressi Stefano Franscini) conference Hand, Brain and Technology 2018 is held on the Monte Verità in Ascona, Switzerland.



1 Museo Casa Anatta
2 Casa Selma
3 Elisarion "Chiaro nel mondo dei beati"
4 Casa dei Russi
5 Centro congressuale
6 Albergo Bauhaus
7 Villa Semiramis
8 Casa Amicizia
9 Ristorante con terrazza panoramica
10 Bar Roccia
11 Bar Piscina (eventi)
12 Spazio open-air Piscina
13 Percorso "Arcobaleno di Chiara"
14 Tennis
15 Giardino delle erbe
16 Progetto tè verde
17 Casa Loreley
18 Casa Giovanna
19 Casa Gioia
20 Casa Marta
--- Sentiero

TRANSPORTATION

There will be a **FREE SHUTTLE SERVICE** (from Locarno train station to Monte Verità). We are offering a limited number of seats in a shuttle from the train station in Locarno to the conference venue on Monte Verità on the arrival and departure day. This shuttle is based on a first-come, first-served basis, with the following departure timetable:

Sunday, August 26, 2018 (Departure from Locarno)	**Friday, August 31, 2018** (Departure from Monte Verità)
15:20	13:20
16:00	14:00
16:40	14:40
17:20	15:20
18:00	16:00
18:40	16:40

For public transportation throughout Switzerland consult www.sbb.ch/en.

WIRELESS LAN

You will find access information for the Wi-Fi in the conference bag. Additional to the wireless LAN, a computer room at the conference venue is available for the participants.

PUBLIC EVENT

More Than Skin Deep:
What haptic illusions can teach about the brain

Thursday, 30th August 2018
Auditorium, Monte Verità, Ascona
8:30 - 9:30 pm – Mix of show and presentation
9:30 - 10:00 pm – Questions from the public

Free entrance, reservation appreciated: info@csf.ethz.ch, tel. 091 785 40 54/56

Prof. Dr. Peter Brugger[1], Prof. Dr. Vincent Hayward[2]

[1] University Hospital Zurich, Zurich
[2] Sorbonne Université Pierre et Marie Curie, Paris

We all know how easily our eyes can trick us into believing that a straight line is curved, a white surface is coloured, or that a friendly face is distorted. But we are much less aware of the fact that our sense of touch is as much subject to illusions as is the visual sense. This interactive demonstration will introduce you to the world of haptic illusions, and explore what they might tell us about the brain. You will experience flat surfaces that are felt to be curved, objects that are heavier than they should be, equally sized sticks that feel different, or tubes that become longer like Pinocchio's nose. Illusions on your own body will also be shown. You will feel sensations on a plastic hand as if it was your own, trick your brain in rejecting sensations on your own skin, or experience "phantom touch". While these demonstrations should convince you that illusions are at your fingertips, you will find the explanations suggested by the two experts as informative about your own self as they are entertaining.

EXCURSION & CONFERENCE DINNER

As one of the highlights of the "Hand, Brain and Technology" conference, we invite you to join us for a scenic excursion to discover the beautiful countryside of our host region Ticino on the afternoon of Wednesday, August 29th. The program includes a stroll through beautiful Locarno followed by a tour and show at the Falconeria Locarno and a lakeside dinner in the Blu Restaurant & Lounge, with a stunning view on the Lago Maggiore. Sponsored by the Clinica Hildebrand - Centro di Riabilitazione Brissago, this excursion promises to be a wonderful opportunity to engage with your fellow attendees in the unforgettable surroundings of the southern side of the Swiss Alps.

Program:

15:00: Bus from Monte Verità to Casinò Locarno
Optional: 15min walk from Monte Verità to the pier of Ascona and a 30min boat ride to the pier of Locarno (Departures from Ascona at 13:55 and 15.25, 8.50 CHF fee)

15.15: Arrival at Casinò Locarno for an on-your-own-sightseeing tour through the picturesque village
Recommendation: Cable-car ride up to the stunning Madonna del Sasso (7.20 CHF fee) and/or a walk across the Piazza Grande.

16:45 Bus from the Casinò Locarno to the Falconeria Locarno, for an exciting experience in the world of birds of prey and their astonishing grasping abilities (tour and show)

18.30: Transfer to the Blu Restaurant & Lounge, in Locarno, with a hosted apéro on the lakeside terrace and a four-course dinner.

23.30: Bus transfer back to Monte Verità

For more information follow the links below or see https://www.ticino.ch/

Falconeria Locarno
Via delle Scuole 12, 6600 Locarno
http://falconeria.ch/?lang=en

BLU Restaurant & Lounge
Via Gioacchino Respini 9, 6600 Locarno
www.blu-locarno.ch/en

Madonna del Sasso
Via Santuario 2, 6644 Orselina

Piazza Grande
Piazza Grande 14, 6600 Locarno

Organized with the kind support of:

CLINICA HILDEBRAND
Centro di riabilitazione Brissago

SPECIAL LECTURE BY LEAH KRUBITZER

Evolution of the forelimb and cortical areas associated with limb use in mammals.

L. Krubitzer, PhD[1*]

[1] University of California, Davis, US

Abstract

Forelimb morphology and use in mammals is extraordinarily diverse. Evolution has produced wings, flippers, hooves, paws and hands which are specialized for a variety of behaviors such as flight, swimming and grasping. While there is a wealth of data in human and non-human primates on the role of motor cortex and posterior parietal cortical areas in reaching and grasping with the hand, these cortical networks did not arise de novo in primates but likely arose from simpler networks. Yet, we know relatively little about how frontoparietal networks that control the forelimb have evolved. Previously our laboratory has examined the organization of somatosensory cortical areas in a variety of mammals and found that both morphology of the limb and how the limb is used are reflected in the organization of cortical fields. In the current study we examine the organization of movement maps using intracortical microstimulation techniques in a range of mammals to determine the extent of cortex from which movements can be evoked, and how behavioral specializations of the limb are represented in movement maps in the cortex. While some features of organization are similar across species, such as gross topography, most of the details of map organization are species specific and are more variable across species than are somatosensory maps. Further, movement representations are variable across individuals within a species suggesting that they are, in large part, a product of experience. This supposition is supported by studies in which we examined movement maps in rats reared in semi natural conditions in which the outdoor enclosure was 3000 times larger than standard laboratory cages. We found that motor maps contained representations of complex movements involving the forelimbs, hindlimbs and tail compared to laboratory reared animals indicating that early movement experience impacts motor map organization.

References

Baldwin MKL, Cooke DF, Goldring AB, Krubitzer L (2017) Representations of Fine Digit Movements in Posterior and Anterior Parietal Cortex Revealed Using Long-Train Intracortical Microstimulation in Macaque Monkeys. Cereb Cortex, [Epub ahead of print] PMID:29136133.

Baldwin MKL, Cooke DF and Krubitzer L (2016) Complex movement maps in motor, somatosensosensory and posterior parietal cortex in tree shrews. Cerebral Cortex. 27(2): 1439-1456. PMID: 26759478.

Short Biography

Leah Krubitzer is currently a professor in the Department of Psychology and Center for Neuroscience at the University of California, Davis. She received a BS at Penn State University and a PhD in Psychology at Vanderbilt University, Nashville Tennessee. Her graduate work, under the mentorship of Dr. Jon Kaas focused on the evolution of visual cortex in primates. Her work on the evolution of the neocortex was extended in her postdoctoral work at the University of Queensland, Australia to include a variety of mammals such as monotremes and marsupials. While in Australia she performed comparative analysis of the neocortex in a variety of different species and to date has worked on the brains of over 45 different mammals. Her current research focuses on the impact of early experience on the cortical phenotype, and she specifically examines the effects of the sensory environment on the development of connections, functional organization and behavior and seeks to understand how culture impacts brain development. She also examines the evolution of sensory motor networks involved in manual dexterity, reaching and grasping in mammals. She received a MacArthur award for her work on evolution.

PROGRAM

Time	Monday: Neurophysiology	Tuesday: Cognitive Neurosciences	Wednesday: Haptics and Neurorehab	Thursday: Neuroprosthetics/Modelling	Friday: Sensorimotor Control
09h00–09h20	Welcome address	Salvatore M. Aglioti	Hubert Dinse	Silvestro Micera	Stephen H. Scott
09h20–09h40	Sliman Bensmaia				
09h40–10h00		Martin H. Fischer	Alain Kaelin-Lang	Benjamin Tee	Mike D. Rinderknecht
10h00–10h20	Ingvars Birznieks			Giacomo Valle	Andreea Sburlea
10h20–10h50	Coffee	Coffee	Coffee	Coffee	Coffee
10h50-11h10	Roland Johansson	Alessandro Farnè	Katherine J. Kuchenbecker	Robert Gaunt	Derek Kamper
11h10–11h30					
11h30–11h50	Hans Scherberger	Elena Rusconi	Vincent Hayward	Poster session	Yuta Furukawa
11h50–12h10		Silvia Macchione			Chris Versteeg
12h10–12h30	Esther Kuehn	Xaver Fuchs	Felix Thomas		CSF Junior Award ceremony & closing words
12h40–14h30	Lunch	Lunch	Yon Visell	Lunch	Lunch
14h30–14h50	Poster FF	Tamar Makin	13h: Lunch	Lee Miller	Departure
14h50–15h10	Richard A. Andersen		15h: Excursion & Conference dinner		
15h10–15h30		Fabrice R. Sarlegna		Dustin Tyler	
15h30–15h50	Amanda Kaas				
15h50–16h20	Coffee	Coffee		Coffee	
16h20–16h40	Poster FF	Frédérique de Vignemont		Gregory A. Clark	
16h40–17h00	Mackenzie Mathis				
17h00–17h20		Ella Striem-Amit		Yufei Wu	
17h20–17h40	Daniel Huber	Daan Wesselink		Jeffrey Yau	
17h40–18h00	Aldo Faisal	Gianluca Saetta		Laura Edmondson	
18h00–18h20	Benoit Delhaye	General discussion		General discussion	
18h30–20h30	Dinner	Dinner		Dinner	
20h30–21h30	Poster session	Leah Krubitzer		Peter Brugger and Vincent Hayward	

TALKS:

DAILY SCHEDULES AND ABSTRACTS

SECTION	PAGE

NEUROPHYSIOLOGY

Monday, August 27, 2018

09h00 – 09h20	**Welcome address**	
09h20 – 10h00	**Sliman Bensmaia** (U Chicago) *The neural basis of somatosensation in primate cortex*	KEYNOTE
10h00 – 10h20	**Ingvars Birznieks** (U New South Wales) *Talking to the brain in its own language*	KEYNOTE
10h20 – 10h50	Coffee	
10h50 – 11h30	**Roland Johansson** (Umea U) *Fast and accurate macrogeometric tactile processing during object manipulation*	KEYNOTE
11h30 – 12h10	**Hans Scherberger** (German Primate Center, U Göttingen) *Cortical sensory processing for grasping in primates*	KEYNOTE
12h10 – 12h30	Esther Kuehn (DZNE Magdeburg, Max Planck Institute) *Cortical microstructure of the human hand area*	A01T
12h40 – 14h30	Lunch	
14h30 – 14h50	**Poster fast-forward**	
14h50 – 15h30	**Richard A. Andersen** (Caltech) *Advancing Neuroprosthetics with High-Dimensional Control and Stimulation Induced Somatosensory Feedback*	KEYNOTE
15h30 – 15h50	Amanda Kaas (Maastricht U) *Selective responses to vibrotactile frequencies in primary somatosensory cortex*	A02T
16h20 – 16h40	**Poster fast-forward**	
16h40 – 17h20	**Mackenzie Mathis** (Harvard U) *The role of somatosensory cortex during motor adaptation in mice*	KEYNOTE
17h20 – 17h40	**Daniel Huber** (U Geneva) *Frequency selective encoding of substrate vibrations in the somatosensory cortex*	KEYNOTE
17h40 – 18h00	**Aldo Faisal** (Imperial College London) *Towards understanding the dynamical representations for hand control*	KEYNOTE
18h00 – 18h20	Benoit Delhaye (U Chicago) *Rapid geometric feature signaling in the spiking activity of populations of tactile nerve fibers*	A03T
18h30 – 20h30	Dinner	
20h30 –	**Poster session (Sala Balint)**	

Toward the neural basis of stereognosis: Neural coding of hand proprioception and touch

Bensmaia, Sliman J.[1]*

[1] Department of Organismal Biology and Anatomy, University of Chicago, US.

Abstract

The hand, our primary means of interaction with objects, comprises a deformable sensory sheet: The relative position of receptors in the skin depends on the conformation of the hand. When we grasp an object, we can sense its three dimensional structure from somatosensory signals from the hand without the contribution of vision. This ability – stereognosis – requires the integration of tactile and proprioceptive signals from the hand. While proprioception provides information about the global shape of an object, touch provides information about the local contours of the object at the points of contact with the hand. How the nervous system goes about integrating these two streams of information is largely unknown.

Part of the problem is that little is known about how the conformation of the hand is represented in the brain. To fill this gap, we investigated how hand movements and postures are represented in somatosensory cortex. To this end, we had animals perform a grasping task while we tracked its hand movements and recorded from somatosensory neurons. We then characterized the response properties of these neurons using the Generalized Linear Model. We found that individual neurons respond to multiple joints distributed over the hand. Furthermore, we find that they are more sensitive to the posture of the hand than its movements, in contrast to neurons that encode the proximal limb. Interestingly, the multi-joint response fields of individual neurons were unrelated to the correlations of hand joints. That is, the set of joints encoded by a given neuron were not necessarily highly correlated with one another during grasp. This, in turn, raises the question of what principles guide representations of hand posture in cortex.

As mentioned above, proprioception only provides information about the global shape of an object. To study how local contours of an object are encoded, we continue to investigate the neural basis of touch. Most recently, we have characterized the representation of natural textures in somatosensory cortex. Texture perception operates over six orders of magnitude – from hundreds of nanometers to tens of millimeters – so affords us an opportunity to investigate the principles of tactile processing over the range of tangible spatial scales. We find that somatosensory cortex carries a high dimensional representation of texture. The principal axis of this representation is highly predictive of perceived roughness. Another axis encodes spatial scale, with one extremum encoding coarsely textured surfaces and the other finely textured ones. The two extrema seem to receive their strongest input from different populations of nerve fibers.

Finally, the lab is embarking on the challenging journey of probing proprioceptive and tactile representations in a touch, inching ever closer to the holy grail of stereognosis.

Short Biography

Bio: Dr. Sliman Bensmaia received a B.A. in Cognitive Science from the University of Virginia in 1995, and a PhD in Cognitive Psychology from the University of North Carolina at Chapel Hill, in 2003, under the tutelage of Dr. Mark Hollins. He then joined the laboratory of Dr. Kenneth Johnson, at the Johns Hopkins University Krieger Mind/Brain Institute, as a postdoctoral fellow. In 2009, Dr. Bensmaia joined the faculty in the Department of Organismal Biology and Anatomy at the University of Chicago, where he is also a member of the Committees on Neurobiology and on Computational Neuroscience. Bensmaia is a leading expert on the neural basis of somatosensation in human and non-human primates, which his laboratory investigates by combining psychophysics, neurophysiology, and computational modeling. Bensmaia also seeks to apply insights from basic science to develop approaches to convey sensory feedback in upper-limb neuroprostheses.

Talking to the brain in its own language

Ingvars Birznieks[1,2]* and Richard Vickery[1,2]

[1] School of Medical Sciences, UNSW Sydney, Australia.
[2] Neuroscience Research Australia, Sydney, Australia.

Abstract

To address the challenge of understanding how tactile information is encoded by tactile afferents and then interpreted by the brain, we developed stimulation methods that enabled us to create neural firing patterns in peripheral afferents with a precisely controlled temporal structure. As all information from tactile receptors is communicated to the brain via spike train patterns, and we can design and create virtually any arbitrary spike train pattern using non-invasive pulsatile mechanical stimuli, we now have the opportunity to correlate controlled changes in the firing pattern and timing of individual spikes with changes in perceptual qualities evoked by these stimuli. Our experiments clearly demonstrate that features of stimuli reflected only in the temporal pattern of spike trains do determine perception and thus must be utilized at some levels of neural processing. We have found that vibrotactile frequency perception depends on the duration of silent gaps between spike bursts, regardless of the spike count within the burst. We also have evidence that low spiking rates in FAII afferents are consciously perceived and the frequency easily discriminated, indicating that FAII afferents are suitable for detecting fast discrete mechanical transients with low repetition rate as might arise during object manipulation or exploration of surfaces with sparsely distributed sharp asperities or ridges. These findings contribute to the understanding of the fundamental principles of receptor and neural specificity and how the nervous system combines such inputs to ensure stimulus perception constancy.

References

Khamis, H., Redmond, S.J., Macefield, V., Birznieks I. (2014) Classification of Texture and Frictional Condition at Initial Contact by Tactile Afferent Responses. In: Auvray M., Duriez C. (eds) Haptics: Neuroscience, Devices, Modeling, and Applications. EuroHaptics 2014. Lecture Notes in Computer Science, vol 8618. Springer, Berlin, Heidelberg

Birznieks, I, Vickery R.M. (2017). Spike Timing Matters in Novel Neuronal Code Involved in Vibrotactile Frequency Perception. Current Biology, 27, 1485–1490.

Short Biography

Dr Ingvars Birznieks is a sensory neurophysiologist interested in tactile sensory information encoding mechanisms. He received his PhD training at Umeå University in Sweden focusing on tactile sensory control of dexterous manipulation in humans. During his postdoctoral period he moved to Australia, first to the University of Melbourne and then to Neuroscience Research Australia in Sydney. After his postdoctoral studies he has fulfilled his long-standing ambition to establish his own research laboratory and create an inter-disciplinary research network linking neuroscience, biomedical engineering and clinical neurology.

Dr Ingvars Birznieks is a senior research fellow at Neuroscience Research Australia and senior lecturer at UNSW Sydney.

Fast and accurate macrogeometric tactile processing during object manipulation

Roland S Johansson[1]*

[1] Department of Integrative Medical Biology, Umea University, Umea, Sweden

Abstract

The populations of first order tactile afferent neurons that innervate the inside of the hand signal soft tissue transformations that occur when the hand interacts with objects, thus providing moment-to-moment information about the contact state between the object and the hand. A critical aspect of dexterous object manipulation is that the relevant spatiotemporal tactile information is sufficiently accurate and that it can be used quickly and efficiently by the brain. My talk addresses encoding and use of tactile afferent information in the control of manual dexterity. In particular, I discuss how the peripheral organization of first order tactile neurons in humans might promote rapid and automatic processing of macrogeometric tactile information required to control fingertips in fine manipulation tasks. The emphasis is on population coding and representation of object location and orientation within fingertips based on objects' edge-based features.

Key Words: Human, Hand, Touch, Tactile system, Neurons/physiology, Fine motor skills, Object manipulation

References

Pruszynski, J. A., Flanagan, J. R. and Johansson, R. S. (2018). Fast and accurate edge orientation processing during object manipulation. Elife, 7. doi:10.7554/eLife.31200

Pruszynski, J. A. and Johansson, R. S. (2014). Edge-orientation processing in first-order tactile neurons. Nat Neurosci, 17(10): 1404-1409. doi:10.1038/nn.3804

Johansson, R. S. and Flanagan, J. R. (2009). Coding and use of tactile signals from the fingertips in object manipulation tasks. Nature Reviews Neuroscience, 10(5): 345-359.

Short Biography

Johansson received his MD/PhD 1978 at Umeå University, and in 1988 he became a full professor in physiology at the same university. His research primarily addresses the organization and function of the neural mechanisms that give our hands their extraordinary sensorimotor skills, with focus on the hands' tactile sensory innervation and on multimodal sensorimotor control mechanisms crucial to dexterity. In addition, he has contributed with pioneering research in human orofacial neurophysiology and muscle physiology. During his career, Johansson has received several academic honors and awards and since 2004 he is a member of the Royal Swedish Academy of Sciences.

Cortical sensory processing for grasping in primates

Hansjörg Scherberger[1,2]*

[1] Neurobiology Laboratory, German Primate Center (DPZ), Göttingen, Germany
[2] Faculty of Biology and Psychology, University of Göttingen, Germany

Abstract

Hand function plays an important role in all primate species, and its loss is associated with severe disability. Grasping movements are complex motor acts for which the brain needs to integrate sensory and cognitive signals to generate behaviourally meaningful actions. To achieve this computation, specialized brain areas in the primate parietal (anterior intra parietal area, AIP), premotor (area F5), and primary motor cortex (M1 hand area) are functionally connected.

This presentation highlights recent experimental results in non-human primates to characterize how these cortical areas generate grasping movements on the basis of sensory signals. Tactile and visual sensory information is represented in these grasp-related areas, but only when they are behaviorally relevant for the preparation of grasping actions. Furthermore, the processing of visual and tactile information for preparing the same grasping action seems to be distinct in these areas, indicating different sensori-motor processes for preparing visually-based and tactilely-based grasping actions, even at the level of premotor cortex. Sensorimotor transformation from different sensory sources might therefore take quite distinct pathways for the same motor act.

Short Biography

Hans Scherberger received his Master in Mathematics (1993) and his Medical Doctor (1996) from Freiburg University, Germany. He currently heads the Neurobiology Lab at the German Primate Center and is Professor for Primate Neurobiology at Göttingen University (since 2008). He was trained in systems electrophysiology at the University of Zurich (1995-1998) and the California Institute of Technology (1998-2003) before leading a research group at the Institute of Neuroinformatics at Zurich University and ETH (2004-2009). His research focuses on neural coding and decoding of hand movements and their interactions with sensory systems.

Cortical microstructure of the human hand area

Esther Kuehn*[1,2,3], Nikolaus Weiskopf[3], Martin Sereno[4], Thomas Wolbers[1,2]

[1] DZNE Magdeburg, Germany
[2] Center for Behavioral Brain Sciences Magdeburg, Germany
[3] Max Planck Institute for Human Cognitive and Brain Sciences Leipzig, Germany

Abstract
The microstructure of the cortex gives unique and unprecedented insights into the organizational principles of human brain function. In particular, cortical myeloarchitecture determines the speed and precision of neuronal input-output signal flows, and changes in myeloarchitectonic patterns differentiate adjacent cortical fields. Here, we used a novel and recently validated technology offered by ultra-high field imaging at 7 Tesla to describe for the first time the in-vivo layer-dependent cortical myeloarchitecture of the human hand area in primary somatosensory cortex. Individual changes in cortical myelination in different cortical layers were related to basic hand functions such as tactile perception and tactile discrimination, as well as to grip strength and motor control. Myelination in middle layers of primary somatosensory cortex was investigated in particular detail to determine whether myelin-poor borders could be identified within the somatosensory representation of the hand (using similar methodology as in Kuehn et al. 2017 and Kuehn et al. 2018). In contrast to current textbook knowledge, my data show that cortical myeloarchitecture in the human hand area is not homogenous, but presents with area-specific as well as layer-specific profiles that can be related to individual hand function. Individual as well as group-coherent differences in cortical myeloarchitecture reveal organizational principles that may be used to explain short-term as well as long-term plasticity-related changes in human hand function.

References
Kuehn, E., Dinse, J., Jakobsen, E., Long, X., Schäfer, A., Bazin, P.L., Villringer, A., Sereno, M.I. and Margulies, D.S. (2017). Body Topography Parcellates Human Sensory and Motor Cortex. Cereb Cortex, 27(7): 3790–3805.

Kuehn, E., Haggard, P., Villringer, A., Pleger, B., Sereno, M.I. (2018). Visually-driven maps in area 3b. J Neurosci, 38(5): 1295-1310.

Short Biography
In the course of my PhD (2009-2013) that I conducted at the Max Planck Institute for Human Cognitive and Brain Sciences, I used 7 Tesla fMRI to show that fine-grained finger maps in human area 3b can be activated by pure vision of touch. During my postdoc at UCL, I focused on structure-function mapping, and showed that myelin-poor septa separate the representations of the hand and the face in human S1. Since 2015, I work as postdoctoral fellow at the German Center for Neurodegenerative Diseases and focus on microstructural imaging of the sensorimotor system and aging.

Advancing neuroprosthetics with high-dimensional control and stimulation induced somatosensory feedback

Richard Andersen[1*]

[1] California Institute of Technology, Pasadena, USA

Abstract

To explore how high-level intentions may be used for neural prosthetic applications, we have implanted microelectrode arrays in the presumed human analog of the anterior intraparietal cortex (AIP) in tetraplegic participants. In non-human primates AIP neurons have been found to encode hand shapes for grasping behaviors. We find that individual neurons in human AIP are tuned to particular imagined hand shapes and these hand shapes can be decoded from the population activity.

Surprisingly, we also find that AIP is very high dimensional coding a variety of variables including movements of both hands and both shoulders, observed actions, and memory based decisions. We find that the variables are mixed on individual neurons, but the mixing is not random and has structure. Strategy (attempted or imagined movements) and body side (left or right) are more overlapping in the population and effector (shoulder or hand) is more separated. We refer to this organization as partially mixed selectivity. Computations that are similar may be more overlapping whereas those that may interfere with each other may be more separated. This high dimensional coding is an advantage for neural prosthetics as a great deal of information can be read out from a single array in AIP.

Bidirectional brain machine interfaces (BMIs) would not only read out intended movements, but also would close the loop by providing somatosensory feedback to improve object manipulation. We implanted two microelectrode arrays for intracortical microstimulation in primary somatosensory cortex of a tetraplegic participant. The participant reported cutaneous and proprioceptive sensations in the contralateral arm with microstimulation. For microelectrodes in which more than one sensation could be elicited, we found that proprioceptive sensations were associated with higher amplitudes of stimulation. The natural quality of the percepts, the stimulation of both cutaneous and proprioceptive sensations, and the variation of percept modality with stimulus amplitude are promising results for advancing the somatosensory feedback component of a bi-directional interface.

Short Biography

Andersen studies the neurobiological underpinnings of brain processes including the senses of sight, hearing, balance and touch, the neural mechanisms of action, and the development of neural prosthetics. He is a member of the National Academy of Sciences (USA), the National Academy of Medicine (USA), and the American Academy of Arts and Sciences. He is the James G. Boswell Professor of Neuroscience and the T&C Chen Brain-Interface Center Leadership Chair at Caltech. He is currently Director of the T&C Chen Brain Machine Interface Center and the Swartz Center for Theoretical Neurobiology at Caltech.

Selective responses to vibrotactile frequencies in primary somatosensory cortex

Amanda Kaas[1,2]*, Judith Eck[1,2], Till Steinbach[1], Valentin Kemper[1,2], Rainer Goebel[1,2,3]

[1] Department of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, UNS 40, 6229 ER Maastricht, The Netherlands
[2] Maastricht Brain Imaging Center, Maastricht University, Maastricht, The Netherlands
[3] The Netherlands Institute for Neuroscience, an Institute of the Royal Netherlands Academy of Arts and Sciences (KNAW), Amsterdam, The Netherlands

Abstract

According to standard neuroscience textbooks, primary somatosensory cortex contains columns that respond selectively to information from rapidly and slowly adapting afferents. This is supported by neurophysiological (Sur et al. 1981) and intrinsic optical imaging data (Friedman et al. 2004) from non-human primates. However, to our knowledge, such selectivity has never been shown in humans. The current study uses ultra-high field 7T functional magnetic resonance imaging (fMRI) to investigate whether frequency information can be decoded from the primary somatosensory cortex (S1) finger region in healthy humans. To identify the region of interest (ROI) for slice positioning and subsequent analyses, we performed a finger mapping in which the fingertips of right hand D2, D3, and D4 were stimulated with 25Hz vibrotactile stimulation. In three subsequent runs, only the fingertip of right hand D3 received a pseudorandom sequence of 1Hz and 25Hz stimulation, in order to preferentially activate neurons responsive to information form the slowly adapting type 1 and rapidly adapting type 1 afferents. Stimulation was delivered at three different amplitudes to rule out potential confounding effects of differences in perceived intensity.

In preliminary data from three participants (1 male, 2 female), we found S1 voxels with a frequency preference, defined as a significant t-value that was higher for one or the other condition. Using a leave-one-run out support vector machine procedure on t-values extracted from three different anatomical S1 ROIs presumed to correspond to regions BA1, BA2 and BA3, we found above chance frequency classification in BA1, whereas amplitude could not be classified above-chance.

This study provides first evidence for frequency preference in human S1. Future research could investigate whether this is more pronounced at cortical depths corresponding to feedforward processing. These findings could be used to develop models on how tactile inputs are combined to form representations relevant to object manipulation.

References

Sur, M. Wall, J.T., Kaas, J.H. (1981). Modular Segregation of Functional Cell Classes Within the Postcentral Somatosensory Cortex of Monkeys. Science, 212(4498): 1059-1061.

Friedman, R.M., Chen, L.M., Roe, A.W. (2004). Modality maps within primate somatosensory cortex. PNAS, 101(43): 12724-12729.

Short Biography

Amanda Kaas obtained her PhD at Maastricht University in 2006 investigating the neural and behavioral basis of active touch and tactile working memory, She went on to do a post-doc at the MPI for Brain Research, Frankfurt a.M., Germany with Dr. Lars Muckli, using fMRI to study visual mental imagery. In 2008, she became a postdoc with Professor Rainer Goebel, investigating somatosensory strategies for fMRI Brain-Computer Interfacing. Currently, she is an assistant professor at the Cognitive Neuroscience Department, Maastricht University, the Netherlands. Her research focuses on somatosensory processing and (maladaptive) somatosensory plasticity after learning, in chronic pain and stroke.

Somatosensory Cortex Plays an Essential Role in Forelimb Motor Adaptation in Mice

Mackenzie Mathis[1]*

[1] The Rowland Institute at Harvard, Harvard University. Cambridge, MA USA

Abstract
Our motor outputs are constantly re-calibrated to adapt to systematic perturbations. This motor adaptation is thought to depend on the ability to form a memory of a systematic perturbation, often called an internal model. However, the mechanisms underlying the formation, storage, and expression of such models remain unknown. Here, we developed a mouse model to study forelimb adaptation to force field perturbations. We found that temporally precise photoinhibition of somatosensory cortex (S1) applied concurrently with the force field abolished the ability to update subsequent motor commands needed to reduce motor errors. This S1 photoinhibition did not impair basic motor patterns, post-perturbation completion of the action, or their performance in a reward-based learning task. Moreover, S1 photoinhibition after partial adaptation blocked further adaptation, but did not affect the expression of already-adapted motor commands. Thus, S1 is critically involved in updating the memory about the perturbation that is essential for forelimb motor adaptation.

References
Mathis, M.W., Mathis, A. and Uchida, N. (2017) Somatosensory Cortex Plays an Essential Role in Forelimb Motor Adaptation in Mice. Neuron, doi: 10.1016/j.neuron.2017.02.049

Short Biography
I was a PhD student at Harvard University with Prof. Naoshige Uchida from 2013 to 2017, where I worked on establishing a mouse model of forelimb motor adaptation. I was then briefly a post-doctoral fellow with Prof. Matthias Bethge at the University of Tübingen, before starting my own group as a Rowland Fellow at Harvard in September 2017.

Frequency selective encoding of substrate vibrations in the somatosensory cortex

Daniel Huber[1]*

[1] Department of Basic Neurosciences, University of Geneva, Switzerland

Abstract

Sensing vibrations that propagate through solid substrates conveys fundamental information about moving objects and other nearby dynamic events. Here we report that neurons responsive to substrate vibrations applied to the mouse forelimb reveal a new way of representing frequency information in the primary somatosensory cortex (S1). In contrast to vibrotactile stimulation of primate glabrous skin, which produces temporally entrained spiking and frequency independent firing rates, we found that mouse S1 neurons rely on a different coding scheme: their spike rates are conspicuously tuned to a preferred frequency of the stimulus. Histology, peripheral nerve block and optogenetic tagging experiments furthermore reveal that these responses are associated with the activation of mechanoreceptors located in deep subdermal tissue of the distal forelimb. We conclude that the encoding of frequency information of substrate-borne vibrations in the mouse S1 might be analogous to the representation of pitch of airborne sound in auditory cortex.

References

Prsa M, Huber D. (2018). Frequency selective encoding of substrate vibrations in the somatosensory cortex. bioRxiv

Short Biography

I studied Zoology in Zürich in Rüdiger Wehner's department and followed up with PhD in Neuroscience at the University of Lausanne. After a postdoctoral stay in Karel Svoboda's lab in Cold Spring Harbor and HHMI's Janelia Research campus, I opened my own lab in 2012 at the University of Geneva. My lab combines various cutting edge optical tools and novel behavioral paradigms in mice and mouse lemurs to study the cortical circuits involved in sensory-motor integration and neuroprosthetic learning.

Towards understanding the dynamical representations for hand control

A. Aldo Faisal[1,2,3]*

Brain & Behavior Lab: [1] Dept. of Computing, [2] Dept. of Bioengineering,
[3] Data Science Institute, Imperial College London, London SW7 2AZ, UK,

Abstract

We can accurately determine the shape of objects from haptic feedback, even in the absence of vision and manipulate unseen objects with ease in our fingers. This is possible because our brains perform neural operations on haptic sensory information which require to date unclear encoding strategies and unknown computations. While much of the effort in understanding human haptic function has been based on perceptual mechanisms, we are currently exploring both sensorimotor and cognitive-level understanding of haptic function. We explore normative approaches and ask how should representations of hand and finger proprioceptive be encoded? We will present current work from our lab reflecting on efficient sensory coding of dynamical finger actions and computational models that can explain how in-hand object manipulations with our fingers allows us to simultaneously localise and map objects.

References

Faisal, A., Stout, D., Apel, J., & Bradley, B. (2010). The manipulative complexity of Lower Paleolithic stone toolmaking. *PloS one*, *5*(11), e13718.

Hecht, E. E., Gutman, D. A., Khreisheh, N., Taylor, S. V., Kilner, J., Faisal, A. A., ... & Stout, D. (2015). Acquisition of Paleolithic toolmaking abilities involves structural remodeling to inferior frontoparietal regions. *Brain Structure and Function*, *220*(4), 2315-2331.

Short Biography

Dr. Faisal is Associate Professor of Neuroethology at the Depts. of Bioengineering and Computing at Imperial College London. Aldo read Computer Science and Physics in Germany, and moved to study Biology at Cambridge University (Emmanuel College) and wrote his M.Phil. thesis on the electrophysiological and behavioural study of a complex motor behaviour in freely moving with Malcolm Burrow FRS. For his Ph.D. he joined Simon Laughlin FRS group at the Zoology Department in Cambridge investigating the biophysical sources of neuronal variability. He was elected a Junior Research Fellow at Cambridge University (Wolfson College) and joined the Computational & Biological Learning Group (Engineering Department) to work with Daniel Wolpert FRS on human sensorimotor control. He is since 2016 also director of the Behaviour Analytics at the Data Science Institute, London.

Rapid geometric feature signaling in the spiking activity of populations of tactile nerve fibers

Benoit P Delhaye[1]*, Xinyue Xia[1], Sliman J Bensmaia[1]

[1] Department of Organismal Biology and Anatomy, University of Chicago, Chicago, IL

Abstract

The dexterous manipulation of objects requires the extraction of geometric features at each contact location. To button a shirt, for instance, requires precise information about orientation of the button with respect to the fingertips, and this information is typically not available visually. The longstanding theory is that local geometric features are extracted from the spatial layout of the response of populations of tactile nerve fibers (*1*, *2*). However, recent evidence suggests that edge orientation can be extracted very quickly (<130ms)(*3*), casting doubt on the spatial layout hypothesis, which presumably requires that neuronal signals be integrated over time. An alternative hypothesis is that orientation is conveyed in precise temporal spiking patterns, which in principle can lead to quicker information transmission (*4*). Here, we simulate the responses of tactile afferent from the entire fingertip (~800 afferents) to edges indented into the skin, using a recently developed and validated model of the afferent responses (*5*). We then assess how quickly and accurately edge orientation can be extracted from the population response. First, we use a machine learning (ML) approach to gauge the limits of the orientation information carried in the population response. We find that population responses can lead to high angular accuracy (< 3°) within a very short period of time (<50ms), and this signal does not rely on precise spike timing. Second, we implement a biomimetic decoder of orientation, consisting of a bank of oriented Gabor filters, designed to mimic the responses of cortical neurons. We find that the biomimetic approach leads to orientation decoding performance that approaches the limit set by the ML and is more robust to changes in other stimulus features. Finally, we show that orientation signals in cortex follow a time course consistent with our biological decoding approach.

References

[1] Johnson, Kenneth O., and Steven S. Hsiao. "Neural mechanisms of tactual form and texture perception." Annual review of neuroscience 15.1 (1992): 227-250.

[2] Goodwin, Antony W., and Heather E. Wheat. "Sensory signals in neural populations underlying tactile perception and manipulation." Annu. Rev. Neurosci. 27 (2004): 53-77.

[3] Pruszynski, J. Andrew, J. Randall Flanagan, and Roland S. Johansson. "Fast and accurate edge orientation processing during object manipulation." eLife 7 (2018): e31200.

[4] Johansson, Roland S., and Ingvars Birznieks. "First spikes in ensembles of human tactile afferents code complex spatial fingertip events." Nature neuroscience 7.2 (2004): 170.

[5] Saal, Hannes P., et al. "Simulating tactile signals from the whole hand with millisecond precision." Proceedings of the National Academy of Sciences 114.28 (2017): E5693-E5702.

Short Biography

Benoit Delhaye is a postdoctoral fellow at the University of Chicago. He holds a Master's degree in electro-mechanical engineering and a PhD in app§lied science from l'Université Catholique de Louvain (Belgium). He seeks to understand how tactile receptors and their associated nerve fibers encode information about contacted objects, and how the brain uses these signals to guide dexterous manipulation. Approaches include precise measurements of the skin response during object interactions, analysis and modeling of tactile afferent responses, and quantification of sensory outcomes. An important component of his work is the application of these insights towards the development of algorithms to electrically stimulate the nerve to restore somatosensory feedback in bionic hands.

COGNITIVE NEUROSCIENCE

Tuesday, August 28, 2018

09h00 – 09h40	**Salvatore M. Aglioti** (U Rome, IRCCS) *Vicarious experience of painful, pleasant, and intimate touch through immersive virtual reality*	KEYNOTE
09h40 – 10h20	**Martin H. Fischer** (U Potsdam) *Numbers are handy concepts*	KEYNOTE
10h20 – 10h50	Coffee	
10h50 – 11h30	**Alessandro Farnè** (Lyon Neuroscience Research Center) *Grasping and Sensing the World through Tools*	KEYNOTE
11h30 – 11h50	Elena Rusconi (U Trento) *Individual differences in tactile tests of finger gnosis correlate specifically with symbolic number skills (but not with other Gerstmann's functions) in primaryschool children*	B01T
11h50 – 12h10	Silvia Macchione ((Lyon Neuroscience Research Center, U Lyon) *RSS-induced tactile improvement transfers from one hand to the other one*	B02T
12h10 – 12h30	Xaver Fuchs (Bielefeld U) *Active tactile search improves localization of touch*	B03T
12h40 – 14h30	Lunch	
14h30 – 15h10	**Tamar Makin** (UC London) *Functional consequences of S1 reorganisation in amputees?*	KEYNOTE
15h10 – 15h50	**Fabrice R. Sarlegna** (CNRS, Aix-Marseille U) *Loss of Proprioception Impacts Perception, Action and Cognition: Evidence from Deafferented Patients*	KEYNOTE
15h50 – 16h20	Coffee	
16h20 – 17h00	**Frédérique de Vignemont** (CNRS, Jean Nicod Institute) *How much can one extend one's body?*	KEYNOTE
17h00 – 17h20	Ella Striem-Amit (Harvard U) *Visual, somatosensory and motor neural action systems in people born without hands*	B04T
17h20 – 17h40	Daan Wesselink (UC London, U Oxford) *Obtaining and maintaining cortical hand representation: evidence from acquired and congenital handlessness*	B05T
17h40 – 18h00	Gianluca Saetta (University Hospital Zurich) *Apparent motion perception in upper limb amputees with phantom sensations "obstacle shunning" and "obstacle tolerance"*	B06T
18h00 – 18h20	**General discussion**	
18h30 – 20h30	Dinner	
20h30 – 21h30	**Lea Krubitzer** (U California)	KEYNOTE

Vicarious experience of painful, pleasant, and intimate touch through immersive virtual reality

Salvatore Maria Aglioti[1,2]*, Martina Fusaro[2,3], Matteo Lisi[1,2], Gaetano Tieri[2,3]

[1] Sapienza University of Rome, Rome, Italy
[2] Fondazione Santa Lucia, IRRCS, Rome, Italy
[3] Unitelma Sapienza, Rome Italy

Abstract

Seeing other people being touched or painfully stimulated activates similar brain areas as when we experience touch or pain ourselves. Immersive Virtual Reality (IVR) is a new powerful tool that allows researchers to create extremely veridical vicarious experiences.

To explore the behavioural and bodily reactivity to observed pain and pleasant touch, we performed a series of studies based on a novel paradigm in which healthy participants immersed in a virtual reality scenario observed a virtual needle penetrating (pain) or a virtual hand caressing (pleasure) the hand of an avatar seen from a first (1PP)- or a third (3PP)-person perspective. Explicit (i.e. VAS ratings of the experience associated to observation of each stimulus and referred to the self- or to others) and implicit measurements (skin conductance reactivity, SCR) were collected. Expanding our previous findings (Fusaro et al., 2016) we show that participants felt high illusory feeling of ownership over the virtual hand only when they observed it in 1PP and received painful or pleasant stimuli. Skin conductance responses showed higher reactivity to painful stimuli regardless the physical perspective (1PP vs 3PP), particularly for the self-related condition.

In a second series of studies, healthy heterosexual, male and female participants embodied an avatar and then underwent touches in different parts (including breast and genitalia) of the virtual body (that was felt as own). In addition to the strong feeling of being touched, participants reported about the different aspects of the experience (social acceptability, sexual arousal, pleasantness) while undergoing SCR recording. Preliminary results indicate that the vicarious experience in virtual reality allows to address more directly delicate issues that can otherwise be explored only through imagination (Suvilehto et al, 2015). Thus, IVR may offer unprecedented opportunities to explore the effect of somatosensory stimuli (like pain and touch) even when they are not actually delivered.

References

Fusaro M , Tieri G, Aglioti SM (2016) Seeing pain and pleasure on self and others: behavioral and psychophysiological reactivity in immersive virtual reality. J Neurophysiol. 2116(6):2656-2662. doi: 10.1152/jn.00489.2016.

Suvilehto JT, Glerean E, Dunbar RI, Hari R, Nummenmaa L. (2015) Topography of social touching depends on emotional bonds between humans. (2015) Proc Natl Acad Sci U S A. 112(45):13811-6. doi: 10.1073/pnas.1519231112. Epub 2015 Oct 26

Short Biography

Salvatore M Aglioti, trained as behavioral neurologist, he is professor at Sapienza University of Rome and researcher at Fondazione Santa Lucia, IRCCS, Rome (http://agliotilab.org). His research revolves around the brain representation of the bodily self and on the plasticity of somatosensory and motor representations in healthy and brain lesioned people. In the last decade, he addressed a variety of social neuroscience topics ranging from empathy for pain and existential neuroscience to deception and dishonesty in social contexts. Moreover, he performs research on the neural underpinnings of social group coding driven by race as well as by political and religious affiliation.

Numbers are handy concepts

Martin H. Fischer[1]*

[1] Cognitive Sciences, University of Potsdam, Germany

Abstract

The concept of number has traditionally been considered as a prototypical instance of abstract(ed) knowledge. It denotes the size of any arbitrary set of objects, thus seemingly preventing systematic correlations with sensory or motor features. Yet, numerosity does co-vary with physical parameters in manual perception and action. In this presentation, I describe how number processing obligatorily activates sensory and motor features of our hands and vice versa. These bi-directional links suffice to identify numbers as embodied concepts. Implications for research and theorizing will be discussed.

References

Sixtus, E., Lindemann, O., & Fischer, M. H. (2017). Stimulating numbers – signatures of finger counting in numerosity processing. Psychological Research doi: 10.1007/s00426-018-0982-y. [Epub ahead of print].

Sixtus, E., Fischer, M. H., & Lindemann, O. (2017). Finger posing primes number comprehension. Cognitive Processing, 18(3), 237-248. doi:10.1007/s10339-017-0804-y.

Short Biography

Martin Fischer graduated with a PhD in cognitive psychology from University of Massachusetts in 1997 and has since worked in Munich, Dundee and Potsdam on several topics related to embodied cognition. Since 2011 he leads the Potsdam Embodied Cognition Group where the main research focus currently is on semantic modulation of grip force.

Grasping and Sensing the World through Tools

Alessandro Farnè[1]*, Luke E. Miller[2], Vincent Hayward[3]

[1] Impact Lab, Lyon Neuroscience Research Centre
[2] INSERM U1028 ImpAct Team, France
[3] Sorbonne Université Pierre et Marie Curie, Paris

Abstract
Along evolution, humans have reached a high level of sophistication in the way they control their environment. One important step in this process has been the development of tools, enabling humans to go beyond the boundaries of their physical possibilities to both sense and grasp objects. The ability to use tools is one of the most remarkable skills of the human species and, although not a unique feature of the human kind, humans' mastering of tools has reached an exquisite level of complexity. Quite paradoxically, however, we know relatively little of what makes humans such good masters of tools. Grasping through tools is a major challenge for the motor system, in that the control of the hand, otherwise typical final effector, needs to be transferred to the prehensile part of the tool. In the first part of my talk I will present findings suggesting that motor control is not merely distalised from the fingers to a grabber prongs: rather, when we use tools to grasp objects, the body of the tool is incorporated into our arm representation, as shown by both motor and tactile tasks (Cardinali et al, 2009; Martel et al, 2016). Sensing through tools challenges the somatosensory system heavily and allows for extracting a wealth of information from the sensed objects and the sensing tool itself. I will present recent findings showing that distalisation does not apply to tool sensing either. We can localize impacts on the entire surface of a hand-held rod with great accuracy, a phenomenon we termed tool-extended sensing. We also find evidence suggesting that impact-location is encoded by the rod's vibratory response and then decoded by spiking patterns of Pacinian mechanoreceptors in the hand. Together, these findings indicate that rather than mere distal links between the hand and environment, tools are treated by the nervous system as sensorimotor extensions of the body.

References
Cardinali, L., Frassinetti, F., Brozzoli, C., Urquizar, C., Roy, A.C., Farnè, A. (2009). Tool-use induces morphological updating of the body schema. Curr Biol, 19:R478–R479.

Martel, M., Cardinali, L., Roy A.C., Farnè, A. (2016) Tool-use: an open window into body representation and its plasticity. Cognitive Neuropsychology, DOI: 10.1080/02643294.2016.1167678

Miller, LE., Montroni, L., Kuhn, E., Salemme, R., Hayward, V., Farnè, A. (In press) Sensing with tools extends information processing beyond the body.

Short Biography
Alessandro Farnè holds a PhD in neuropsychology from the University of Bologna, Italy (1999). After a post doc at Rice University Huston, he became assistant professor at the University of Bologna (2001). He then got an Inserm Research Director position at the Space & Action lab (2005). He is group leader at the Impact Lab, at the Center for Neuroscience Research in Lyon (INSERM U1028). His research focuses on the behavioral characterization of the cognitive processes underlying spatial perception and motor control of hand and tools.

Individual differences in tactile tests of finger gnosis correlate specifically with symbolic number skills (but not with other Gerstmann's functions) in primary school children

Delia Guagnano[1], Marianna Riello[1], Andreas Kleinschmidt[2], Elena Rusconi[3]*

[1] Department of Neurosciences, University of Parma, Italy
[2] Department of Clinical Neurosciences, University Hospital (HUG) and University of Geneva, Switzerland
[3] Department of Psychology and Cognitive Science, University of Trento, Corso Bettini 31, I-38068 Rovereto, Italy

Abstract

A combination of difficulties in finger gnosis, writing, calculating, and left-right orientation in children has been referred to as developmental Gerstmann syndrome, alluding to Gerstmann's description of this tetrad in adult patients with acquired brain lesions in the dominant posterior parietal lobe (Rusconi, 2018). A debate revolves around the enigmatic, if at all real, functional relation between these symptoms and whether deficits in finger gnosis may play a pivotal role (Miller & Hynd, 2004). In two cross-sectional studies with primary school children (Grades 2-5; no learning disabilities) we probed the cohesiveness of the functions that fail in this tetrad of symptoms. In Study 1, we screened 92 children with a battery of tests that can capture facets of the functions failing in Gerstmann syndrome including tactile tests of finger gnosis and tests of calculation. As a control for functional specificity, we also tested constructional skills. In Study 2, we screened 156 children with representative tests from Study 1 and with additional tests of number processing (parity and magnitude judgments) and visuo-spatial intelligence. In Study 1, we found positive correlations between finger gnosis and constructional skills, constructional skills and left-right orientation, finger gnosis and number skills. Only the latter remained significant after controlling for Grade. Bayesian statistics showed *substantial* evidence for the lack of correlation in the Gerstmann cluster of functions. In Study 2, we found *decisive* evidence for a positive correlation between finger gnosis and number skills, independent of handwriting, left-right orientation, constructional skills, visuo-spatial intelligence and Grade. In conclusion, functions failing in Gerstmann syndrome do not stand out as a distinct and cohesive functional cluster in developmental age. However, our data are consistent with either a functional cross-talk or a common maturational factor specific to finger gnosis (as measured via tactile tests) and symbolic number skills.

References

Rusconi,, E. (2018). Gerstmann syndrome: Historic and current perspectives. In G. Vallar and H.B.G. Coslett (Eds.) *The parietal lobe. Neurological and neuropsychological deficits.* Handbook of Clinical Neurology series, Elsevier.

Miller, C.J. and Hynd, G.W. (2004). Whatever happened to developmental Gerstmann's syndrome? Links to other pediatric, geriatric and other neurodevelopmental syndromes. Journal of Child Neurology, 19, 282-289.

Short Biography

ER received a PhD in Cognitive Sciences from the University of Padua in 2005 and was trained as a postdoctoral researcher in cognitive neuroscience at ICN (UCL Brain Sciences, UK) and Neurospin (France). Afterwards, she held research scientist and teaching fellow positions in a number of institutions in the UK and Italy. In 2013 she was appointed as Reader at Abertay University (UK) and in 2014 she received a PhD in Security Science from UCL Engineering Sciences (UK). Since 2018 she has been working as Full Professor in Psychobiology and Physiological Psychology at the University of Trento (Italy).

RSS-induced tactile improvement transfers from one hand to the other one

Silvia Macchione[1,2,3]*, Dolly-Anne Muret[1,2], Eric Koun[1,2,3], Hubert R. Dinse [4],

Karen T. Reilly[1,2], Alessandro Farnè[1,2,3]

[1] INSERM U1028, CNRS UMR5292, Lyon Neuroscience Research Center, ImpAct Team, Lyon, France
[2] University of Lyon 1, Lyon, France
[3] Hospices Civils de Lyon, Neuro-immersion & Mouvement et Handicap, Lyon, France
[4] Cortical plasticity Laboratory, Department of Theoretical Biology, Institute for Neuroinformatics, Ruhr-University, Bochum, Germany

Abstract

Repetitive somatosensory stimulation (RSS) consists of a few hours of passive stimulation which improves the tactile acuity of a stimulated fingertip without involving any effort or attention by the subject. This experimentally-induced perceptual improvement has long been thought to be highly local and specific to the stimulated region as, when applied to the right-D2, RSS boosts the spatial tactile perception of this finger but not of the homologous left-D2, neither of the adjacent right-D3, nor of the far right-D5. Contrary to the large evidence for its local nature, recent work from our group challenged this view since we found that RSS on the right-D2 improves tactile acuity not only at this finger, but also at the level of the face. The finding revealed that RSS can actually induce also remote behavioral effects, and this calls the question about how it is possible that improvement goes to the face but does not transfer a little nearby, to other fingers. In three behavioral psychophysics experiments (including a double-blind control experiment), we mapped out the tactile improvement induced remotely by RSS over the face and hands, namely the index, thumb and middle fingers of both hands. Besides replicating the hand to face remote improvement, we found that both fingers adjacent to the stimulated one in the opposite hand (left-D1 and left-D3) were also improved, whereas no change was observed for their homologues within the RSS stimulated hand (right-D1 and right-D3). There results demonstrate that RSS-induced tactile improvement is not only local in hands, but it spreads from one hand to the other one.

References

Godde B, Spengler F, Dinse HR. Associative pairing of tactile stimulation induces somatosensory cortical reorganization in rats and humans. Neuroreport 8, 281–285 (1996).

Muret D, Dinse HR, Macchione S, Urquizar C, Farnè A, Reilly KT. Touch improvement at the hand transfers to the face. Current Biology, R736-737 (2014).

Short Biography

Silvia Macchione is a PhD candidate in Neuroscience and Cognition at the University of Lyon1 (France), based in the ImpAct Team under the supervision of Alessandro Farnè. She obtained her MSc in Experimental and Applied Biology at the University of Pavia (Italy). Her current work is using repetitive somatosensory stimulation (RSS) to induce somatosensory plasticity; in particular the PhD project focuses on the investigation of the RSS-induced perceptual consequences and their spatial boundaries among different body regions. A particular focus for Silvia's future prospective is on the use of RSS as adjuvant approach to improve performances of patients with somatosensory deficits, for example stroke patients.

Active tactile search improves localization of touch

Xaver Fuchs[1]*, Dirk U. Wulff[2,3], Tobias Heed[1]

[1] Biopsychology & Cognitive Neuroscience, Faculty of Psychology & Sports Science, Bielefeld University, Bielefeld, Germany
[2] Center for Cognitive and Decision Science, University of Basel, Basel, Switzerland
[3] Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany

Abstract

Visual localization often uses a two-step strategy: Gaze is first directed from far away to near the target; a second saccade then uses online visual information to correct the remaining error. This two-step strategy is very efficient in terms of reducing memory capacities because information about the environment does not need to be stored in detail, but can be accessed online when it is needed. In touch localization, error can arise from inaccuracy of tactile, proprioceptive and motor systems. For a movement towards a touch, the 2D skin target location must be converted into a 3D target location for the finger. We tested whether two-step search strategies using online sensory feedback exist in the tactile system and compensate initial errors in localization of touch on the skin.

Participants received brief touches on their forearm with their eyes closed. During localization, they first touched their arm with their opposite index finger and were allowed to then correct the indicated location by moving the finger on the arm.

We observed improvements in localization in most (~70%) trials. Larger improvements were evident especially when initial errors were large. Improvements in localization mainly occurred in the first half of on-skin trajectories, whereas later adjustments usually did not reduce error.

We conclude that inaccuracy in tactile localization can be compensated by tactile search strategies using online sensory information especially when the discrepancies between the target and initial localizations are large. Accordingly, most tactile localization experiments have potentially overestimated localization error, because online tactile feedback and adjustment are usually prevented. These improvements may imply a similar two-step strategy as in vision. Nevertheless, localization improvement in the vicinity of the target seems limited. Loss of efficiency in the course of search trajectories suggests that, at least on the arm, remaining errors cannot be fully compensated.

References

Tatler, B. W., & Land, M. F. (2011). Vision and the representation of the surroundings in spatial memory. Philosophical Transactions of the Royal Society B: Biological Sciences, 366(1564), 596–610.

O'Regan, J. K. (1994). The World as an Outside Iconic Memory – No Strong Internal Metric Means No Problem of Visual Stability. Behavioral and Brain Sciences, 17(2), 270.

Short Biography

Xaver Fuchs studied psychology at the University of Marburg. During his PhD in Herta Flor's lab at the Central Institute of Mental Health in Mannheim, he studied neural and perceptual changes in amputees with phantom limb pain as well as the role of visuotactile integration in the embodiment of artificial limbs. In 2017, Xaver joined Tobias Heed's lab at Bielefeld University as a postdoctoral researcher. His current research interests are (1) bidirectional relationships between body representations and the processing of touch and pain and their integration with other senses and (2) the relationship between pain, touch and movement control.

Hand plasticity: Use-dependent S1 reorganisation in amputees

Tamar R. Makin[1]*

[1] Institute of Cognitive Neuroscience, University College London, UK

Abstract

I will present recent results and ideas about how the brain adapts to extreme changes in resources, due to hand loss and the need to pick up alternative behavioural strategies. I will explore the neural correlates of a range of "alternative hands", including extraordinarily dexterous toepfoot usage and artificial limbs. Based on these findings I will challenge some of the basic textbook assumptions about the triggers and barriers of brain plasticity, and suggest an alternative framework for the process of brain reorganisation in the sensorimotor hand area.

References

Hahamy A, Macdonald SN, van den Heiligenberg F, Kieliba P, Emir U, Malach R, Johansen-Berg H, Brugger P, Culham JC, Makin TR. (2017). Representation of Multiple Body Parts in the Missing-Hand Territory of Congenital One-Handers. Curr Biol. 8;27(9):1350-1355

TR Makin, F de Vignemont, AA Faisal. (2017) Neurocognitive barriers to the embodiment of technology Nat. Biomed. Eng 1, 0014

Short Biography

I am a neuroscientist at UCL's Institute of Cognitive Neuroscience, heading the London Plasticity Lab. My main interest is in understanding the key drivers and limitations of reorganisation in the adult brain. A particular focus is on how changed hand function, e.g. due to prosthesis usage or robotic fingers augmentation, shapes brain reorganisation. For this purpose, I integrate methods from the fields of neuroscience, experimental psychology and rehabilitation. A primary model for this work is studying individuals with a hand loss. I hope my research will enable clinicians to guide amputees and related clinical populations to take advantage of the benefits of brain reorganisation, rather than to suffer from their adverse effects.

Loss of Proprioception Impacts Perception, Action and Cognition: Evidence from Deafferented Patients

Fabrice Sarlegna[1]*

[1] Institute of Movement Sciences, CNRS & Aix-Marseille University, France

Abstract

Loss of proprioception is known to be debilitating for the everyday life of numerous individuals such as stroke patients or Parkinson Disease patients. To determine the specific contribution(s) of proprioceptive signals to motor control and learning, we have studied rare individuals who, after a massive Sensory Neuropathy, suffered a massive loss of the large-diameter sensory afferents. This has resulted in a severe impairment in the perception of position and movement sense about the body's segments. Despite motor pathways and motor learning seem unaffected, movement control is severely impaired. This is evidenced by the immense difficulties in walking, which typically result in the use of a wheelchair, abnormal limb drift without visual feedback, and large motor variability without and also with visual feedback. The somatosensory deficit likely resulted in the development of compensatory cognitive strategies. Overall, loss of proprioception largely impacts the everyday life of such deafferented patients and likely explains some of the deficits observed in other neurological patients. These findings, combined with those of fundamental research on healthy individuals, highlight the role of proprioception for perception and action control. Visual feedback mechanisms can only partially compensate for a massive proprioceptive loss, indicating that developments in sensory substitution and rehabilitation are necessary to optimize functional recovery.

References

Sarlegna, F. R., Malfait, N., Bringoux, L., Bourdin, C., Vercher, J.-L. (2010) Force-field adaptation without proprioception: Can vision be used to model limb dynamics?, Neuropsychologia, 48: 60–67.

Miall, R.C., Kitchen, N. M., Nam, S.-H., Lefumat, H., Renault, A. G., Ørstavik, K., Cole, J., Sarlegna, F. R. (2018) Proprioceptive loss and the perception, control and learning of arm movements in humans: Evidence from sensory neuronopathy. Experimental Brain Research, 236: 2137–2155.

Short Biography

Fabrice Sarlegna is a research scientist of the CNRS, the French National Center for Scientific Research. He obtained a PhD in Human Movement Sciences from the University of the Mediterranean in 2004 and was a postdoctoral fellow at Penn State University (USA) before joining the Institute of Movement Sciences. His work focuses on the theoretical understanding of human motor behaviour, in particular the control of upper-limb movements in healthy young and older adults, as well as neurological patients. Currently, his main line of work consists in examining the specific roles of vision and proprioception in motor planning, predictive control, online control and adaptation.

Stretching the body: Can one tickle a tool?

Frederique de Vignemont[1]*

[1] Institut Jean Nicod, ENS, Paris, France

Abstract
We extend our body a hundred times a day by using tools, which enable us to do more and farther away, and possibly even to feel farther away. More and more findings can be taken as evidence for the embodiment of tools. However, I shall consider three possible limits to tool embodiment. First, one may ask whether one feels sensations in tools *in the same way* as one feels sensations in one's body. Second, one may ask whether one feels *the same types of sensations* in tools, and in particular pain, itch and tickle. Third, one may ask whether one can feel *a sense of ownership* for tools. I shall conclude that it is beneficial for tools NOT to be fully embodied.

References
de Vignemont, F. (2018). *Mind the body*: *An exploration of bodily self-awareness* Oxford University Press.

Short Biography
Frederique de Vignemont is a senior researcher at the Jean Nicod Institute. Her work is at the crossroad of philosophy and cognitive science. Her interest includes the self, the distinction between body schema and body image, touch, bodily ownership, peripersonal space, and more recently pain. In her book that she just published, she provides a comprehensive treatment of bodily awareness and of the sense of bodily ownership, combining philosophical analysis with recent experimental results from cognitive science. She also edited a multidisciplinary volume on the body and the self (*The Subject's matter*, MIT Press, 2017).

Visual, somatosensory and motor neural action systems in people born without hands

Ella Striem-Amit[1]*, Gilles Vannuscorps[1,2,3], Moritz Wurm[1,2], Alfonso Caramazza[1,2]

[1] Department of Psychology, Harvard University, Cambridge, MA, 02138, USA
[2] Center for Mind/Brain Sciences, Università degli Studi di Trento, Mattarello, 38122, Italy
[3] Faculty of Psychology and Educational ciences and Psychological Sciences Research Institute, Université catholique de Louvain, Louvain-la-Neuve, 1348, Belgium

Abstract

What determines the role of brain regions, and their plasticity when typical inputs or experience is not provided? To what extent can extreme compensatory use affect brain organization?

I present studies conducted on people born without hands (upper-limb dysplasics) showing that manual sensory-motor experience is not required for the development of several hand-selective association brain systems. These include an intact hand-tool conjoint selectivity in the ventral visual cortex despite the life-long use of feet to manipulate tools, and intact action observation decoding in the ventral and dorsal streams. Movement of the foot, used as an effector by the dysplasics, selectivity engages an anterior intraparietal sulcus hand-selective region, suggesting potential retention of this region's role in effector-tool interaction. In contrast to the retained function in the visual association cortices, the primary somatosensory and motor cortices of the dysplasics show a reorganization based on neuroanatomical constraints such as topographic proximity and connectivity, and not on functional effector-use. These are selectively activated by the close-by shoulder, and not for the compensatorily-used foot, as is found in late-onset amputation or deafferentation.

These findings suggest that the visual and visuomotor association action system, in contrast to the primary sensorimotor cortex, does not rely on sensorimotor experience or simulation. Instead, the data suggest that these regions pertain to computations which are abstracted from motor low-level components, similarly to the visual-independence of the same networks in people born blind. The organization of these cortical regions is therefore highly dependent on innate (prenatal) constraints reflecting computational preferences. These findings also open new questions of the ability to utilize the effector-independent organization in the action system for motor rehabilitation.

References

Striem-Amit, E., Vannuscorps, G. and Caramazza, A. (2017) Sensorimotor-independent development of hands and tools selectivity in the visual cortex. Proc Natl Acad Sci U S A 114(18):4787-4792.

Striem-Amit, E., Vannuscorps, G. and Caramazza, A. (2017) Limitations of compensatory plasticity: the organization of the primary sensorimotor cortex in foot-using bilateral upper limb dysplasics. bioRxiv.

Short Biography

Dr. Ella Striem-Amit is a postdoctoral fellow at Harvard University psychology department. Her research uses neuroimaging to study the balance between innate organization and plasticity in the human brain. Specifically, she focuses of the effects of congenital sensory-motor deprivation, in conditions such as blindness, deafness and dysplasia (being born without hands).

Obtaining and maintaining cortical hand representation: Evidence from acquired and congenital handlessness

Daan B Wesselink[1,2]*, Fiona M.Z. van den Heiligenberg[2], Naveed Ejaz[3,4], Harriet Dempsey-Jones[1,2], Lucilla Cardinali[3,5], Aurelie Tarall-Jozwiak[6], Jörn Diedrichsen[3,4], Tamar R Makin[1,2]

[1] Institute of Cognitive Neuroscience, University College London, London, UK
[2] FMRIB Centre, Nuffield Department of Clinical Neuroscience, University of Oxford, Oxford, UK
[3] Brain and Mind Institute, University of Western Ontario, Canada
[4] Department of Computer Science, University of Western Ontario, Canada
[5] Unit for Visually Impaired People, Istituto Italiano di Tecnologia, Genoa, Italy.
[6] Queen Mary's Hospital, London, UK

Abstract

Hand representation in the primary somatosensory cortex (SI) is thought to be shaped and maintained by experience. However, although the fine characteristics of digit topography could be fine-tuned by altered behaviour, overall hand structure is highly stable across people and time [1]. Recently, we even showed that three amputees experiencing highly vivid phantom sensations maintain cortical representation of their missing hand [2]. Still, it is unclear whether this persistence of hand representation depends on experiencing vivid phantom sensation, or whether it is immune to the long-term withdrawal of sensory feedback.

In this study, we scanned 18 unilateral amputees (17±10 years since amputation) with varying degrees of phantom sensations, as well as individuals with congenital unilateral limb absence (without phantom sensations) and two-handed controls. Inside a 3T MRI scanner, all participants performed individual digit movements with either hands (missing/non-dominant and intact/dominant hand), as well as a more demanding motor synergy task with their intact hand. Using representational similarity analysis, we interrogated the inter-digit (activity) pattern structure within the SI hand area.

The deprived cortex, contralateral to amputees' missing hand, was activated by movement of both phantom digits and the (ipsilateral) intact hand. In both cases, the representational structure of the hand was stable, as we found no differences between the pattern structure of amputees and that of controls. The deprived cortex was stable in all amputees; this did not depend on perceived phantom sensations (assessed using questionnaires). In contrast, the representation of congenital one-handers' missing hand was severely diminished. Finally, activation of ipsilateral resources (e.g. amputees' deprived cortex) during high motor demands alluded to a functional role in (intact) hand motor control.

Together, our findings suggest that once cortical organisation is formed, it is remarkably persistent, despite drastic loss of afferent input and lack of sensory experience.

References

[1] Ejaz, N., Hamada, M., & Diedrichsen, J. (2015) Hand use predicts the structure of representations in sensorimotor cortex. *Nat. Neurosci.*, 18, 1034–1040.

[2] Kikkert, S., Kolasinski, J., Jbabdi, S., Tracey, I., Beckmann, C.F., Berg, H.J., & Makin, T.R. (2016) Revealing the neural fingerprints of a missing hand. *eLife*, 5, e15292.

Short Biography

Daan Wesselink is a PhD candidate at University of Oxford and works both at the Welcome Centre for Integrative Neuroimaging (Oxford) and the Institute of Cognitive Neuroscience (University College London). He uses MRI to study somatosensory representation in the human cortex. More specifically, his work examines the boundaries of sensorimotor plasticity following changes in input.

Apparent motion perception in upper limb amputees with phantom sensations: "obstacle shunning" *and* "obstacle tolerance"

Gianluca Saetta[1]*, Arjan Gijsberts[2], Matteo Cognolato[3,4], Manfredo Atzori[3], Valentina Gregori[2], Cesare Tiengo[5], Franco Bassetto[5], Barbara Caputo[2], Henning Müller[3], Bigna Lenggenhager[6], Peter Brugger[1]

[1] Department of Neurology, Neuropsychology Unit, University Hospital Zurich, Switzerland
[2] Center for Nano Science and Technology @Polimi, Istituto Italiano di Tecnologia, Milan, Italy
[3] Information Systems Institute, University of Applied Sciences Western Switzerland (HES-SO), Sierre, Switzerland
[4] Rehabilitation Engineering Lab – Department of Health Sciences and Technology, ETH Zurich, Switzerland
[5] Clinic for Plastic Surgery, University Hospital of Padova, Padova, Italy
[6] Department of Psychology, Cognitive Neuropsychology, University of Zurich, Switzerland.

Abstract

Phantom limbs (PLs) are thought to either hinder or facilitate the successful embodiment of a prosthesis depending on how they interact with physical objects. PLs with "Obstacle Shunning" (OS) tend to fade off from bodily awareness when their phenomenal space overlaps that of a physical object. Alternatively, PLs can also be experienced to pass through solid objects ("Obstacle Tolerance" - OT). Here we tested how these characteristics of the phantom influence apparent motion perception of human limbs involving either solidity or biomechanical constraints. Depending on stimulus onset asynchrony (SOA), alternation between two static pictures generates the illusory perception that the limb passes through the object (short SOA) or rotates around it along a biologically feasible way (long SOA). Combining multiple behavioural and gaze indices we tested 9 upper limb amputees (4: OS, 5: OT) and 8 able-bodied controls. Upper limb stimuli could be observed either either from a first (1pp) or from a third (3pp) person perspective. The former is thought to trigger a motor simulation of the illusory movements while the latter is arguably mere based on visual processing. Multilevel logistic regressions showed that illusory percepts of amputees compared to controls were less modulated by the factor perspective, suggesting that the mapping of an observed movement onto a PL relies more on a visual rather than motor strategy. Furthermore, OS participants tended to perceive a hand to go through a solid object while in the OT group, PLs pose the same constraints as for an intact hand. These findings, together with findings in lower limb amputees [1], suggest an interaction between the everyday characteristics of the PL and apparent motion perception. This might open new tools for diagnostics and rehabilitation, considering that currently assessments of altered body representation are mainly based on self-report and explicit measures.

References

[1] Saetta, G., Grond, I., Brugger, P., Lenggenhager, B., Tsay, A. J., & Giummarra, M. J. (2018). Apparent motion perception in lower limb amputees with phantom sensations: "obstacle shunning" and "obstacle tolerance". Cortex, 104, 220-231.

Short Biography

Gianluca Saetta is a PhD candidate in Clinical and Cognitive Neuroscience at University Hospital of Zurich. He completed his master's degree in Cognitive Neuroscience and his research internship at University Milano-Bicocca investigating the neurophysiological underpinnings of complex body representation disorders. Combining methods from behavioural neurology, psychology and artificial intelligence, his actual research interests are the multisensory and plastic mechanisms leading to the construction of an unitary and coherent body representation in both healthy participants and in clinical populations. A particular focus is on traumatic amputees with phantom sensations, persons with congenitally absent limbs and individuals with xenomelia.

HAPTICS AND NEUROREHAB

Wednesday, August 29, 2018

09h00 – 09h40	**Hubert Dinse** (U Bochum) *Brains at your fingertips - Driving human plasticity and learning through sensory stimulation*	KEYNOTE
09h40 – 10h20	**Alain Kaelin-Lang** (Neurocenter of Southern Switzerland, EOC) *Neurological disorders of the hand: the neglected role of somatosensory inputs*	KEYNOTE
10h20 – 10h50	Coffee	
10h50 – 11h30	**Katherine J. Kuchenbecker** (Max Planck Institute) *Tactile Reality*	KEYNOTE
11h30 – 12h10	**Vincent Hayward** (Sorbonne U, U London) *Tactile Mechanics*	KEYNOTE
12h10 – 12h30	Felix Thomas (University Hospital Balgrist, ETH Zurich) *Importance of somatosensory input during cooperative hand movements for stroke rehabilitation*	C01T
12h30 – 12h50	Yon Visell (U California) *Touch contact elicits mechanical waves that efficiently encode information in manual interactions*	C02T
13h00 – 15h00	Lunch	
15h00 – 21h30	Excursion & conference dinner	

Brains at your fingertips - Driving human plasticity and learning through sensory stimulation

Hubert R. Dinse[1]*

[1] Neural Plasticity Lab, Institute for Neuroinformatics, Ruhr-University Bochum, Germany
[2] Department of Neurology, BG Hospital Bergmannsheil, Ruhr-University Bochum, Germany

Abstract
Achieving high-level perceptual or behavioral performance is generally considered to require intense training. While it is well-accepted that training and practicing drives neuronal plasticity processes, the underlying synaptic plasticity mechanisms are far from understood. Recent work, however, suggests that training may not be necessary for enhancing performance. Instead, perception and behavior can be effectively modulated by a complementary approach in which plasticity and learning occur in response to mere exposure to repetitive sensory stimulation (Beste & Dinse 2013. The rationale for this training-independent learning is to translate protocols that induce plasticity at a cellular level into sensory stimulation protocols. We have suggested that the surprising effectiveness of this approach applied in different sensory domains stems from the fact that the sensory stimulation protocols used are optimized to alter synaptic transmission and efficacy. Training-independent learning offers the unique opportunity to directly link synaptic plasticity research to human behaviour and learning. This presentation summarizes recent findings showing that this approach induces lasting changes in perception in humans without any explicit task training. Training-independent learning has been used to evaluate the functional relevance of timing-specific synaptic plasticity protocols for improving human behaviour, and to explore novel timing conditions in terms of their ability to drive human learning, which have not been studied at the cellular level so far. Finally, training-independent learning has been successfully applied as therapeutic intervention in patients suffering from brain damage. The potential perspectives of training-independent learning to augment cognition and behaviour and its use in rehabilitation will be discussed.

References
Beste, C. and Dinse, H.R. (2013). Learning without Training. Current Biology, 23: R489–R499.

Short Biography
Hubert Dinse heads the Neural Plasticity Lab at the Institute for Neuroinformatics, and is Senior Scientist at the Neurological Hospital. After a postdoc at the Universita di Pisa, Italy, he worked as a consultant for the Battelle-Institute. From 1988 to 1989, and in 1991 he was Visiting Professor at the University of California, San Francisco. He is Director of Haptic Research and Technology Corporation. He holds German and US patents about brain stimulation applications. His main research interests are tactile and haptic perception, learning and plasticity, aging, development of novel learning and stimulation protocols for targeted neuroplasticity, rehabilitation and therapy.

Neurological disorders of the hand: The neglected role of somatosensory inputs

Alain Kaelin-Lang[1]*

[1] Neurocenter of Southern Switzerland and University of Southern Switzerland, Lugano, Switzerland

Abstract
In clinical neurology, sensory and motor systems disorders are classically considered as separate entities. Accordingly, motor disorders of the hand such as paralysis after stroke, writer's cramp, or slowness of movement due to Parkinson's disease, are considered as motor diseases. However, in all these disorders, the somatosensory systems plays an important yet neglected role. Not only the immediate somatosensory feedback is relevant but also the modulation of motor system plasticity by the sensory afferences. This is particularly important in the field of neurorehabilitation. Several strategies include manipulation of the somatosensory system, e.g. in the form of training by passive movement. Peripheral electrical nerve stimulation has also been proposed as a simple, painless method of enhancing rehabilitation of motor deficits. Several physiological studies both in animals and in humans indicate that a prolonged period of patterned peripheral electrical stimulation induces short-term plasticity at multiple levels of the motor system. Small-scale studies in humans indicate that these plastic changes are linked with improvement in motor function, particularly in patients with chronic motor deficits after stroke. Somatosensory-mediated disinhibition of motor pathways is a possible underlying mechanism. We will review recent evidences about the somatosensory-motor system interaction in human motor disorders and its role in neurorehabilitation.

References
Kaelin-Lang A (2008). Enhancing rehabilitation of motor deficits with peripheral nerve stimulation. NeuroRehabilitation. 23(1):89-93.

Short Biography
Alain Kaelin obtained his medical degree in 1991 in Berne and specialized in neurology. From 1999 to 2001, he accomplished a fellowship in movement disorder and neurophysiological research at the NINDS, in Bethesda, Maryland. From 2001 to 2013 he was the head of the Movement Disorders Center in the Neurology Department of the University of Berne. He also obtained a PhD in Neuroscience and was associate professor since 2012. He is now medical director of the Neurocenter of Southern Switzerland and is since 2017 full professor of neurology at the newly founded Biomedical Faculty of the University of Southern Switzerland.

Tactile Reality for Tool-Mediated Interactions

Katherine J. Kuchenbecker[1]*

[1] Max Planck Institute for Intelligent Systems, Stuttgart, Germany

Abstract

Touching an object causes rich haptic cues that enable you to understand the object's physical properties and adeptly control the interaction. Although human experience centers on physical contact with tangible items, few computer systems provide the user with high-fidelity touch feedback, limiting their intuitiveness. This talk will demonstrate via two recent examples that well-designed tactile feedback can greatly increase the realism of virtual worlds touched through a tool-based haptic interface. First, we created a simple visuo-audio-tactile simulator to help dental students learn to find cavities in teeth. The user watches a video of a real dental tool interacting with a tooth while simultaneously feeling an authentic rendering of the associated contact vibrations. Second, we created highly realistic haptic virtual surfaces by recording and modeling what a user feels when touching 100 real objects with an instrumented stylus. The perceptual effects of displaying the resulting data-driven friction forces, tapping transients, and texture vibrations were quantified by having users compare the original surfaces to their virtual versions. While much work remains to be done, we are starting to see the tantalizing potential of systems that leverage tactile cues to allow a user to interact with virtual environments as though they were real.

References

Kuchenbecker, K.J., Parajon, R., and Maggio, M.P. (2017) Evaluation of a vibrotactile simulator for dental caries detection. Simulation in Healthcare, 12(3):148–156.

Culbertson, H., and Kuchenbecker, K.J. (2017) Importance of matching physical friction, hardness, and texture in creating realistic haptic virtual surfaces. IEEE Transactions on Haptics, 10(1): 63–74.

Short Biography

Katherine J. Kuchenbecker directs the Haptic Intelligence Department at the MPI for Intelligent Systems in Stuttgart, Germany; her team studies haptic interfaces, teleoperation, physical human-robot interaction, and tactile sensing and perception. She was previously a faculty member at the University of Pennsylvania, a postdoc at JHU, and a student at Stanford University. She delivered a TEDYouth talk in 2012, and she has received several honors including a 2009 NSF CAREER Award, the 2012 IEEE RAS Academic Early Career Award, a 2014 Penn Lindback Award for Distinguished Teaching, and various best paper and best demonstration awards.

Tactile Mechanics

Vincent Hayward[1,2,3]*

[1] Sorbonne Universités, UPMC Univ Paris 06, UMR 7222, ISIR, 75005 Paris, France
[2] School of Advanced Study, University of London, London, UK
[3] Actronika SAS, Paris, France

Abstract

The astonishing variety of phenomena resulting from the contact between fingers and objects may be regarded as a formidable trove of information that can be extracted by organisms to learn about the nature and the properties of objects. This richness, which is completely different from that available to the other senses, is likely to have fashioned our somatosensory system at all levels of its organisation, from early mechanics to cognition. The talk will illustrate this idea through examples and show how the physics of mechanical interactions shape the messages that are sent to the brain; and how the early stages of the somatosensory system *en route* to the primary areas are organised to process these messages.

References

Hayward, V. (2011). Is There a 'Plenhaptic' Function? *Philosophical Transactions of the Royal Society B*, 366(1581):3115–3122.

Jörntell, H., Bengtsson, F., Geborek, P., Spanne, A., Terekhov, A., Hayward, V. (2014). Segregation of tactile input features in neurons of the cuneate nucleus, *Neuron*, 83:1444–1452.

Short Biography

Vincent Hayward is presently on leave from Sorbonne Université. Before, he was with the Department of Electrical and Computer Engineering at McGill University, Montréal, Canada, where he became a full Professor in 2006 and was the Director of the McGill Centre for Intelligent Machines from 2001 to 2004. Vincent Hayward is an elected a Fellow of the IEEE. Since January 2017, he is Professor of Tactile Perception and Technology at the School of Advanced Studies of the University of London, supported by a Leverhulme Trust Fellowship.

Importance of somatosensory input during cooperative hand movements for stroke rehabilitation

Felix Alexander Thomas[1,2]*, Miriam Schrafl-Altermatt[1,2]

[1] Spinal Cord Injury Center, University Hospital Balgrist, 8008 Zürich, Switzerland
[2] Neural Control of Movement Lab, ETH Zürich, 8057 Zürich, Switzerland

Abstract

The highest impact on quality of live and independence after a stroke has the recovery of arm and hand function which most often remains incomplete and is therefore a main focus in rehabilitation programs. It has been shown that cooperative hand movements underlie a task specific neural coupling mechanism which emphasizes a stronger engagement of both hemispheres for the control of both hands. These movements are defined as bimanual, object-oriented, counteractive movements where a kinematic chain between the arms is closed over an object that is manipulated. Here, the role of somatosensory input seems to play a major role. Enhanced ipsilateral somatosensory evoked potentials were first observed in healthy participants. In stroke patients, ipsilateral somatosensory input was even greater from the paretic arm to the unaffected hemisphere compared to the contralateral input. This suggests that during cooperative hand movements, the influence of the unaffected hemisphere on the paretic arm and hand is enhanced (Schrafl-Altermatt and Dietz, 2016). This sophisticated distribution of somatosensory input to unaffected brain areas might have an impact in stroke rehabilitation. It is suggested that training with cooperative hand movements might strengthen the inclusion of the unaffected sensorimotor areas for a more optimized recovery of the paretic limb. However, there is currently no training approach focusing on these movements nor is there a device available which enables such cooperative hand movement training. Currently, the development and application of a novel training strategy and a training device specifically targeting cooperative hand movements to utilize their task-specific somatosensory behavior could provide a novel approach in stroke rehabilitation to enhance functional recovery in stroke patients beyond the current standard.

References

Schrafl-Altermatt M., Dietz V (2016). Neural coupling of cooperative hand movements after stroke: role of ipsilateral afference. Ann Clin Transl Neurol 3:884-888.

Short Biography

I completed my bachelor (B.A) and master (M.Sc) studies in sport and movement sciences from 2009-2015 at the University of Konstanz, Germany. Since December 2016, I am a PhD student in the research group of Prof. Nicole Wenderoth. The project focuses on the investigation of cooperative hand movements which seem to underlie a task-specific sensorimotor control i.e. neural coupling and which is partly preserved in stroke survivors. Based on this neurophysiological mechanism, they might be used as a novel training strategy to improve functional outcome of the upper limb in neurological diseases.

Touch contact elicits mechanical waves that efficiently encode information in manual interactions

Yon Visell[1]*, Yitian Shao[1]

[1] Department of Electrical and Computer Engineering, University of California, Santa Barbara

Abstract

The sense of touch facilitates a large variety of everyday tasks and interactions, but the nature of tactile information that is collected by the human hand is not fully understood. Recent research, including work in our lab, has demonstrated that at tactile frequencies, mechanical signals readily propagate throughout the hand as elastic waves, exciting numerous widespread mechanoreceptive afferents. During common manual interactions, touch elicited waves contain perceptual information that is sufficient to accurately infer the gestures that produced them, the parts of the hand that are in contact with touched objects, and attributes of those objects, such as their surface texture. Here, using a database of natural tactile signals – recordings of distributed skin motion during 4600 manual interactions with ordinary objects – we show that an optimal representation of whole hand tactile signals automatically yields cohesive spatiotemporal patterns that reflect important anatomical and functional specializations in the hand. We apply efficient encoding criteria to infer a lexicon of spatiotemporal tactile primitives that are concentrated at the distal ends of individual phalanges, and flow distally to proximally toward the body. These low dimensional representations preserve as much as 97% of the information that tactile signals carry about the interactions that produced them. The results demonstrate how insight into the structure of natural perceptual scenes can be gained from efficient encoding considerations, may suggest new approaches to understanding early somatosensory processing, and may revise our understanding of the mechanical information in natural tactile signals.

References

Shao, Y., Hayward, V., and Visell, Y. (2016). Spatial Patterns of Cutaneous Vibration During Whole Hand Haptic Interaction. Proceedings of the National Academy of Sciences, 113 (15): 4188-4193.

Shao, Y. and Visell, Y. (2018). Learning Constituent Parts of Touch Stimuli from Whole Hand Vibrations. Proc. IEEE Haptics Symposium, Best Paper Award Runner Up, 2016.

Short Biography

Yon Visell is Assistant Professor at the University of California, Santa Barbara, in the Dept. of Electrical and Computer Engineering, directing the RE Touch Lab (www.re-touch-lab.com). He received the Ph.D. in Electrical and Computer Engineering at McGill University, and was a postdoctoral scholar at the Institute of Intelligent Systems and Robotics at UPMC. Dr. Visell has published more than 70 scientific works, including two edited volumes on haptics and virtual reality. His work has received multiple best paper awards at leading haptics conferences. He was awarded a Google Faculty Research Award in 2016, a Hellman Family Foundation Faculty Fellowship in 2017, and a US National Science Foundation CAREER award in 2018. Dr. Visell is the general co-chair of the 2020 IEEE Haptics Symposium.

NEUROPROSTHETICS AND MODELLING

Thursday, August 30, 2018

09h00 – 09h40	**Silvestro Micera** (EPFL) *The quest for a bionic hand: recent achievements and future perspectives*	KEYNOTE
09h40 – 10h20	Benjamin Tee (NU Singapore) *An Ultra-fast and Large Area Scalable Tactile Electronic Skins*	D01T
09h40 – 10h20	Giacomo Valle (EPFL, Scuola Superiore Sant'Anna) *Comparison of linear frequency and amplitude modulation strategies for intraneural sensory feedback in bidirectional hand prostheses*	D02T
10h20 – 10h50	Coffee	
10h50 – 11h30	**Robert Gaunt** (U Pittsburgh) *Microstimulation of the human cortex to restore somatosensation*	KEYNOTE
11h30 – 12h30	**Poster Session**	
12h40 – 14h30	Lunch	
14h30 – 15h10	**Lee E. Miller** (Northwestern U, RIC) *Reverse engineering somatosensation: Development of a biomimetic neuroprosthesis to restore proprioception*	KEYNOTE
15h10 – 15h50	**Dustin J. Tyler** (Case Western Reserve U) *The Human-Technology Interface in the Periphery: Decoding, Encoding, and the Psychosocial Aspects of Long-Term Integration with the Sensorimotor System*	KEYNOTE
15h50 – 16h20	Coffee	
16h20 – 17h00	**Gregory A. Clark** (U Utah) *Restoring dexterous motor control and biofidelic sensation after hand amputation in humans*	KEYNOTE
17h00 – 17h20	Yufei Wu (Imperial College London) *Modeling Use-dependent Proprioceptive Representations in S1 with Natural Hand Statistics*	D03T
17h20 – 17h40	Jeffrey Yau (Baylor College of Medicine) *Normalization models of cue combination in touch*	D04T
17h40 – 18h00	Laura Edmondson (U Sheffield) *Towards a computational account of somatotopic organization in human somatosensory cortex*	D05T
18h00 – 18h20	**General discussion**	
18h30 – 20h30	Dinner	
20h30 – 21h30	**Peter Brugger and Vincent Hayward**	KEYNOTE

The quest for a bionic hand: Recent achievements and future perspectives

Silvestro Micera[1,2]*

[1] Bertatelli Foundation Chair in Translational NeuroEngineering, Institute of Bioengineering & Center for Neuroprosthetics, Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

[2] Translational Neural Engineering Area, The BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy

Abstract

Replacing a missing upper limb with a functional one is an ancient need and desire. Historically, humans have replaced a missing limb with a prosthesis for many reasons, be it cosmetic, vocational, or for personal autonomy. The hand is a powerful tool and its loss causes severe physical and often mental debilitation. The need for a versatile prosthetic limb with intuitive motor control and realistic sensory feedback is huge and its development is absolutely necessary for the near future.

Among the possible solutions to achieve this goal, interfaces with the peripheral nervous system, and in particular intraneural electrodes, are a very promising choice. In this presentation, the results achieved so far by using thin-film transversal intraneural electrodes (TIMEs) for sensory feedback are summarized.

First, we are going to describe the results achieved during experiments with trans-radial amputees who received TIME implants to restore sensory feedback. In particular, we are going to show how tactile and proprioceptive information can be restored providing also embodiment and pain reduction. The possibility of obtaining more natural and effective sensory feedback using biomimetic encoding algorithms will be also shown. Finally, the next steps to achieve a fully implantable device will be briefly summarized.

Our findings demonstrate that these interfaces are a valuable solution for delivering sensory feedback to subjects with transradial amputation. Further experiments are necessary to better understand the potentials of this approach during chronic experiments.

An Ultra-fast and Large Area Scalable Tactile Electronic Skins

Benjamin C.K. Tee[1,2]*, Wangwei Lee, Yu Jun Tan[2]

[1] Materials Science & Engineering & Electrical and Computer Engineering,
National University of Singapore
[2] Biomedical Institute for Global Health Research and Technology,
National University of Singapore

Abstract

The human somatosensory system relies on an extensive network of mechanoreceptors distributed across the skin to pre-process, digitize and transmit the tactile stimulus [1]. Inspired by such key findings in neuroscience, we developed new strategies to enhance the current state-of-the-art in tactile sensing by a multi-disciplinary approach combining materials development and electronic designs to investigate strategies for scaling electronic versions of skin (e-skins) [2]. Our proposed electronic skin has high dynamic range, and able to resolve sub-millisecond tactile stimulus at sensor densities reaching 100 cm-2. By engineering the strain response of micro-structured materials, we were able to demonstrate that we can extend the range of force sensitivities and manufacture a stretchable electronic skin (>20% strain) on various substrates, such as textiles. It is envisioned that such types of electronic skins can be useful in future soft, wearable rehabilitation suits, surgical tools, and humanoid robots capable of greater dexterous manipulations in unstructured environments with or without visual inputs.

References

[1] R. S. Johansson and J. R. Flanagan, (2009) Coding and use of tactile signals from the fingertips in object manipulation tasks, *Nat. Rev. Neurosci.*, 10 (5): 345–359.

[2] B. C. K. Tee, A. Chortos, A. Berndt, A. K. Nguyen, A. Tom, A. McGuire, Z. C. Lin, K. Tien, W. G. Bae, H. Wang, P. Mei, H. H. Chou, B. Cui, K. Deisseroth, T. N. Ng, Z. Bao, “A skin-inspired organic digital mechanoreceptor,” *Science* 350(6258): 313–316.

Short Biography

Dr. Benjamin C.K. Tee is the President’s Assistant Professor in Materials Science and Engineering Department and Electrical and Computer Engineering Department at the National University of Singapore. He obtained his PhD at Stanford University and was selected as a Singapore-Stanford Biodesign Global Innovation Fellow 2014. He is named one of the prestigious MIT TR35 Innovator (Global) in 2015. He currently leads a multi-disciplinary team to develop new materials and sensor devices technology. His current research interests are in the intersection of materials science, mechanics, electronics and biology, with a focus on high performance and sensitive electronic skins for robotics and healthcare applications.

Comparison of linear frequency and amplitude modulation strategies for intraneural sensory feedback in bidirectional hand prostheses

G. Valle[1,2] *, F. M. Petrini[1], I. Strauss[1], F. Iberite[2], E. D'Anna[1], G. Granata[3], M. Controzzi[2], C. Cipriani[2], T. Stieglitz[4], P. M. Rossini[3], A. Mazzoni[2], S. Raspopovic[1], S. Micera[1,2]

[1] Bertarelli Foundation Chair in Translational Neuroengineering, Centre for Neuroprosthetics and Institute of Bioengineering, School of Engineering École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland.
[2] The BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy.
[3] Institute of Neurology, Catholic University of The Sacred Heart, Policlinic A. Gemelli Foundation, Roma, Italy
[4] Laboratory for Biomedical Microtechnology, Department of Microsystems Engineering–IMTEK, Bernstein Center, BrainLinks-BrainTools Cluster of Excellence, University of Freiburg, Freiburg D-79110, Germany.

Abstract

In the last years several research groups have demonstrated that nerve stimulation by implantable peripheral nerve interfaces can be reliably used to restore sensory feedback to upper limb amputees[1]. It has been shown that sensory neural stimulation improves the performance of hand prosthesis users. Different motor tasks and strategies to transduce the readout of sensors in the hand prosthesis have been tested[2]. Recently, it has been shown that charge and frequency of neural stimulation have a linear relationship with the intensity of the elicited sensation. However, the identification of the stimulations paradigms more suited to encode tactile feedback is still an open question. Here, we developed a bidirectional hand prosthesis, in which the readout of force sensors in the hand linearly drives the amplitude or the frequency of intraneural stimulation, in order to verify whether one approach resulted better than the other in improving motor control performance in two trans-radial amputees. Our findings support the conclusion that intraneural stimulation represents a valuable solution to provide useful sensory information to trans-radial amputees and that the linear amplitude modulation strategy is more reliable than linear frequency modulation approach to exploit in bidirectional prostheses developments.

References

[1] Raspopovic S, Capogrosso M, Petrini FM, Bonizzato M, Rigosa J, Di Pino G, Carpaneto J, Controzzi M, Boretius T, Fernandez E, Granata G, Oddo CM, Citi L, Ciancio AL, Cipriani C, Carrozza MC, Jensen W, Guglielmelli E, Stieglitz T, Rossini PM, Micera S. "Restoring natural sensory feedback in real-time bidirectional hand prostheses," Science Translational Medicine 6:222ra19, 2014.

[2] Graczyk EL, Schiefer MA, Saal HP, Delhaye BP, Bensmaia SJ, Tyler DJ. The neural basis of perceived intensity in natural and artificial touch. Sci Transl Med. 2016 Oct 26;8(362):362ra142.

Short Biography

Giacomo Valle received the B.S. degree in Biomedical Engineering, in 2014, and the M.S. degree in Bioengineering curriculum Neuroengineering & Bio-ICT, in 2016, DIBRIS in University of Genoa, Italy. He worked as Research Assistant at École polytechnique fédérale de Lausanne in the Translational Neural Engineering Lab, Lausanne, Switzerland in 2017. He is currently PhD student at the Institute of BioRobotics, Scuola Superiore Sant'Anna, Pisa, Italy. His research interests are in neuroengineering and computational models: neuroprostheses in animal and human models for peripheral stimulation of the nervous system to understand the neural control of movement, prostheses control and the sensory feedback.

Microstimulation of the human cortex to restore somatosensation

Robert Gaunt[1,2,3]*, Sharlene Flesher[4], Chris Hughes[2,3], Jeff Weiss[1], John Downey[5], Angelica Herrera[2,3], Jennifer Collinger[1,2,3,6], Michael Boninger[1,2,6]

[1] Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh PA
[2] Department of Bioengineering, University of Pittsburgh, Pittsburgh PA
[3] Center for the Neural Basis of Cognition, Pittsburgh PA
[4] Department of Neurosurgery, Stanford University, Stanford CA
[5] Department of Organismal Biology, University of Chicago, Chicago IL
[6] Department of Veterans Affairs, Pittsburgh PA

Abstract

Prosthetic limbs controlled by neural interfaces with the cortex have been able to achieve simultaneous control of up to ten degrees of freedom, enabling fast and functional reach and grasp tasks. However, creating a cortical interface that can also restore the sensory capabilities of a healthy limb has been the topic of significantly less research. In 2015 we implanted microelectrode arrays into the primary motor and somatosensory cortices of a person with a cervical spinal cord injury. Recording from populations of single neurons in motor cortex enable him to grasp, transport and manipulate objects using a robotic prosthesis. The electrode arrays implanted in the hand region of area 1 of somatosensory cortex contain 64 individual electrodes split across two microelectrode arrays. Microstimulation through these electrodes evokes different tactile sensations that the participant reports as originating from regions of his own paralyzed hand, even 10 years after spinal cord injury. These percepts have a range of qualities from pressure and touch, to tingling and buzzing. We have found that increasing the stimulus amplitude on a single electrode increases the perceived intensity of the percept, but that changing the stimulus frequency changes the quality of the percept itself. Finally, we have demonstrated that a bidirectional brain interface that includes somatosensory feedback driven by prosthesis sensors enables our study participant to complete object grasp and transport tasks faster and more reliably than he can without sensation. These findings offer proof-of-concept that sophisticated, bidirectional prosthesis control can be achieved through a direct brain interface in people with long-term spinal cord injury.

References

Flesher S.N., Collinger J.L., Foldes S.T., Weiss J.M., Downey J.E., Tyler-Kabara E.C., Bensmaia S.J., Schwartz A.B., Boninger M.L., and Gaunt R.A. (2016). Intracortical microstimulation of human somatosensory cortex.," *Sci Transl Med*, vol. 8, no. 361, pp. 361ra141–361ra141.

Short Biography

Robert A. Gaunt is an Assistant Professor in Physical Medicine and Rehabilitation at the University of Pittsburgh. Robert earned a B.Eng. degree in Mechanical Engineering from the University of Victoria (Victoria BC, Canada) and a Ph.D. in Biomedical Engineering at the University of Alberta (Edmonton AB, Canada). Active research topics include developing novel neural interfaces to regulate bladder function, myoelectric prosthesis controllers for amputees, and bidirectional implantable brain machine interfaces for upper limb prosthesis control. His work has been covered by numerous national and international media outlets.

Reverse engineering somatosensation: Development of a biomimetic neuroprosthesis to restore proprioception

Raeed Chowdhury[1,2], Joseph Sombeck[1,2], Tucker Tomlinson[2], Lee Miller[1,2,3]*

[1] Department of Physiology, Northwestern University, Chicago, IL, 60611, USA
[2] Department of Biomedical Engineering, Northwestern University, Evanston, IL, 60208, USA
[3] Department of Physical Medicine and Rehabilitation, Northwestern University and Rehabilitation Institute of Chicago, Chicago, IL, 60611, USA

Abstract

Relative to the sense of touch, proprioception, the sense of body position and movement, remains quite poorly understood. Furthermore, efforts to replace the sense of proprioception via peripheral or central stimulation lag well behind that of touch. Our conscious sense of proprioception is mostly focused on where are hands are with respect to our body. This is also the basis of the classic model of how neurons in proprioceptive areas of cortex represent reaching movements. We used this model to design experiments to test the effectiveness of ICMS as a means to convey a sense of limb movement in monkeys. While the experiment worked well in one monkey, we were unable to replicate it in subsequent monkeys.

While realistic tactile stimuli can be effectively modeled by discrete, punctate skin indentations, nearly any reaching movement includes length changes in dozens of muscles and stretched skin around the joints that also carries position-related information. It would be unlikely if this information were not represented at some level within S1. We have investigated this question within cortical area 2, a multi-model region of S1. Because simple reaching movements are highly stereotyped, hand movement is highly correlated with movement of the rest of the arm, so it is difficult to determine the importance to these neurons, of the additional degrees of freedom. To decorrelate the arm kinematics from the movement of the hand, we had the monkey make reaching movements in two separate workspaces. Models based on kinematic information from the full arm performed significantly better than the hand-only model.

We are using this and other information about how area 2 neurons combine multi-modal inputs from the arm in an effort to develop more complex, multi-electrode ICMS (mICMS) paradigms that replicate activity recorded across the array during natural limb movements. We predict that these biomimetic patterns will be more readily learnable than random, mICMS patterns.

References

Bensmaia, S. J. and L. E. Miller (2014). "Restoring sensorimotor function through intracortical interfaces: progress and looming challenges." Nat Rev Neurosci 15(5): 313-325.

Tomlinson, T. and L. E. Miller (2016). Toward a proprioceptive neural interface that mimics natural cortical activity. Progress in Motor Control: Theories and Translations. J. Laczko and M. L. Latash, Springer.

Short Biography

Lee E. Miller is a Distinguished Professor of Neuroscience at Northwestern University. He was inducted into the American Institute for Medical and Biological Engineering in 2016, and is the president of the Society for the Neural Control of Movement. Dr. Miller has had a career-long interest in the sensorimotor signals generated by single neurons during arm movement. In the past 10 years, his lab has increasingly focused on brain machine interface technology to restore movement and sensation to paralyzed patients. His interdisciplinary approach has led to productive collaborations locally, nationally, and internationally. He has authored over 100 manuscripts, book chapters, and review articles.

The Human-Technology Interface in the Periphery: Decoding, Encoding, and the Psychosocial Aspects of Long-Term Integration with the Sensorimotor System

Dustin J. Tyler[1*]

1 Dept of Biomedical Engineering, Case Western Reserve Univ., Cleveland, OH

Abstract

Somatosensation is a person's most significant physical and emotional connection to the world. Following limb loss, loss of somatosensation may be more detrimental than the loss of function. To be fully successful as a limb replacement, a prosthetic needs to be incorporated into one's body image and this requires multi-modal sensory congruency. To restore sensation, we have reliably connected the human to the machine through direct peripheral nerve interfaces for providing sensation. Experience in 4 subjects with continual implants for more than 6 years has shown peripheral nerve interfaces to be reliable and functional in connecting individuals with limb loss to their upper limb prostheses (Tan, et. al., 2014). Our work fundamentally addresses two questions. First, is artificially generated activity on sensory peripheral nerves processed and perceived equivalently to natural sensory activity for both perception and modulation of sensorimotor activity? Our chronically implanted interfaces, provide a unique tool that enables us to psychometrically address questions that are not possible with other clinical methods or animal models. Second, does restoration of sensory information lead to incorporation of the artificial limb into the sense of self, improve functional outcomes, and improve psychosocial well-being of individuals with prostheses? The subject feels sensation directly in “their hand.” We have furthered understanding of the relationship between neural code and intensity perception (Graczyk, et. al., 2016); shown that sensory adaptation is not solely a consequence of the physics of the sensory organ; are exploring stimulation patterns as related to sensory quality; and studying where artificial sensation is incorporated in the sensorimotor neural system. Trials of use of the connected device outside the lab show that a direct connection to the human improves the psychosocial impact of the prosthesis and improves the subject's quality of life, thereby leading to longer wear time.

References

Tan, D.W., Schiefer, M.A., Keith, M.W., Anderson, J.R., Tyler, J.D., Tyler, D.J., (2014). A neural interface provides long-term stable natural touch perception. Science Translational Medicine, 6: 257ra138-257ra138.

Graczyk, E.L., Schiefer, M.A., Saal, H.P., Delhaye, B.P., Bensmaia, S.J., Tyler, D.J. (2106). The neural basis of perceived intensity in natural and artificial touch. Science Translational Medicine, 8(142).

Short Biography

Dustin J. Tyler, Ph.D. is the Kent H. Smith Professor of Biomedical Engineering at Case Western Reserve University in Cleveland, OH. He has a secondary appointment as a principal investigator at the Louis-Stokes Cleveland Department of Veterans' Affairs Medical Center (LSCDVAMC) with a prestigious Research Career Scientist award from the Veterans Affairs Rehabilitation Research and Development service. He is the Associate Director of the Advanced Platform for Technology Center, a Department of Veteran's Affairs Rehabilitation Research & Development National Center. Dr. Tyler has over 25 years of experience advancing neuromodulation technology through Class III feasibility clinical research trials.

Restoring High-resolution, Biofidelic Somatosensory Feedback in Humans After Hand Amputation

Gregory A. Clark[1]*

[1] Department of Biomedical Engineering, University of Utah, Salt Lake City, UT, USA

Abstract
The long-term goal of these studies is to provide rich, biofidelic tactile and proprioceptive feedback from a dexterous, sensorized prosthetic hand after prior amputation in humans. Seven human subjects (S1-S7) received one to three 100-electrode Utah Slanted Electrode Arrays (USEAs; Blackrock Microsystems) implanted chronically (1-14 months) in residual median or ulnar nerves 0 to 25 years after transradial amputations. Sensory percepts were evoked by passing current through individual or multiple USEA electrodes (typically biphasic, 100-320 µs, 1-100 µA pulses, at 5-200 Hz). Motor control was provided by decoding neural signals recorded by USEAs and, for S5-S7, by electromyography (EMG) electrodes (Ripple, LLC) implanted in residual extrinsic hand muscles. Subjects reported up to 131 different USEA-evoked cutaneous (e.g., pressure, vibration) or proprioceptive percepts (e.g., joint movement, muscle force), and discriminated among evoked percepts having different phantom spatial locations, intensities, or qualities (*p*'s < 0.01). S6 also discriminated between "soft" and "hard" blocks using a motorized, sensorized DEKA "LUKE" arm having 19 tactile or joint-position sensors that activated USEA stimulation. Biomimetic modes of stimulation incorporating the rate of change as well as absolute stimulus intensity improved compliance discrimination (*p*'s < 0.05). Sensory feedback improved S6's closed-loop motor performance on a fragile "mechanical egg" transfer task (*p*'s < 0.05) and on the Grasping Relative Index of Performance (GRIP) task, which examines speed-precision relationships during grasping of various virtual objects. S6 also showed evidence of embodiment of a prosthetic hand ($p < 0.05$) and a 23% reduction in reported phantom pain ($p < 0.001$). S7, who received electrode implants during an elective transradial amputation after long-term complex regional pain syndrome, could experience a functional sense of touch via USEA stimulation without accompanying pain. These results document an unprecedented level of high-resolution tactile and proprioceptive percepts in humans after hand amputation.

References
Davis, T.S., Wark, H.A.C., Hutchinson, D.T., Warren, D.J., O'Neill, K. III, Schienblum, T., Clark, G.A., Normann, R.A., and Greger, B. (2016) Using a high-electrode-count intrafascicular peripheral nerve interface to restore motor control and sensory feedback in humans with transradial amputations. Journal of Neural Engineering. 13(3):036001.

Wendelken, S., Page, D.M., Davis, T., Wark, H.A.C., Kluger, D.T., Duncan, C., Warren, D.J., Hutchinson, D.T., Clark, G.A. (2017) Restoration of motor control and proprioceptive and cutaneous sensation in humans with prior upper-limb amputation via multiple Utah Slanted Electrode Arrays (USEAs) implanted in residual peripheral arm nerves. Journal of NeuroEngineering and Rehabilitation 14:121.

Short Biography
Gregory A. Clark, Ph.D. is an Associate Professor of Biomedical Engineering and the Director of the Center for Neural Interfaces at the University of Utah. His research seeks to restore sensorimotor function after nervous system damage or disease, such as after hand amputation or spinal cord injury in humans. He is also Chair of the Bioengineering Department Neuroengineering Track, and Curriculum Director of the University Interdepartmental Program in Neuroscience.

Modeling Use-dependent Proprioceptive Representations in S1 with Natural Hand Statistics

Yufei Wu[1]*, Lee E. Miller[5,6,7] and Aldo Faisal[1,2,3,4]

[1] Dept. of Computing, [2] Dept. of Bioengineering, [3] Data Science Institute, Imperial College London, London SW7 2AZ, UK,
[4] MRC London Institute of Medical Sciences,
[5] Dept. of Physiology, [6]Dept. of Physical Medicine & Rehabilitation, Feinberg School of Medicine,
[7] Dept. of Biomedical Engineering Northwestern University, Evanston, Illinois 60208, USA.

Abstract

Upper limb movements are controlled by population activity in primary sensory-motor cortices. Recent work by Ejaz et al. showed that at a macroscopic level the relative arrangement of finger-specific activity patterns in sensorimotor cortex using fMRI matched the correlation structure of finger kinematics in daily life. At a cellular level, however, the organisational principles remain unclear. We thus apply computational methods to study cortical organisation in S1 using natural motor behaviour statistics, following Olshausen's idea of inferring representations in visual cortex from natural image statistics. Natural statistics of body movements were recorded from of right-handed subjects (N=10) in unconstrained daily-life scenarios (4-6h) using an Animazoo IGS-180 motion capture suit. We consider two ways of representing somatosensory information in cortex. One is a topological neural map exploring how representations evolve spontaneously via Hebbian-like synaptic updating rules. By contrast, the other approach comes from a decoding perspective and adapts the neural representation to optimise decoding efficiency under specific constraints like neighbourhood influence, energy and connective efficiency. This is achieved using a new sparse variational autoencoder with Bernoulli sampling. Both models converge to a use-dependent sensory representation of hand motion after being trained with natural hand statistics (simulating somatosensory stimuli of hand motion) in an unsupervised manner. Our models also capture features which have been discovered in S1, including directional-turning responses of individual neurons, similarity in preferred direction in neighbouring neurons. To study our models' capability of reorganisation, we further introduce a situation of amputation by zeroing movement data of a particular joint. Both models re-adapt to a new stable representation in which, we observe a taken-over phenomenon of missing joint neurons by remaining joints.

References

Ejaz, N., Hamada, M., & Diedrichsen, J. (2015). Hand use predicts the structure of representations in sensorimotor cortex. Nature neuroscience, 18(7), 1034.

Short Biography

Yufei is a PhD student at the Department of Computing. Her research interests focus on the intersection between machine learning and neuroscience. She studies sensorimotor learning and control in different aspects, from analysing neural recordings to building computational models of the sensory, motor and cognitive systems in the brain.

Normalization models of cue combination in touch

Jeffrey M. Yau[1]*, Md. Shoaibur Rahman[1]

[1] Baylor College of Medicine, Houston, TX 77030, USA

Abstract

Mundane tasks like fastening a button or tying shoelaces require an extraordinary coordination between the hands. Although there has been tremendous interest in bimanual motor control, much less is known regarding how bimanual sensations are integrated. Cue combination in touch represents a particularly interesting and unique challenge for the nervous system because the skin is deformable: The relative locations of touch receptors in 3D space change as the fingers and limbs are repositioned. Accordingly, bimanual touch likely requires combining what is felt on the hands with where the hands are located in space. Few studies have systematically investigated bimanual touch and the neural computations supporting tactile cue combination are unknown. We addressed these knowledge gaps and discovered that vibration signals are systematically combined over the hands, but idiosyncratically depending on whether attention is deployed toward the frequency or intensity of the tactile cues. Although we observed obligatory cue combination in both the frequency and intensity domains, hand position changes only modulated the former, with bimanual frequency interactions strengthening as the hands are brought closer together. Furthermore, interactions in the frequency domain are characterized by cue attraction while interactions in the intensity domain are only marked by attenuation. To infer the neural computations supporting these idiosyncratic patterns, we conducted rigorous model competitions and identified distinct models that robustly reproduced the bimanual interactions. Notably, cue combination in both domains required divisive normalization, a canonical computation. Our results provide clear demonstrations of tactile cue combination and how proprioception sometimes shapes cutaneous sensing. While the rules governing cue combination in touch appear to be feature-dependent, the critical involvement of normalization in both frequency and intensity interactions reinforces its ubiquity in neural processing.

References

Rahman, M.S., and Yau, J.M. (2018). Normalization models of tactile cue combination. bioRxiv doi: 10.1101/283218.

Short Biography

Dr. Jeff Yau is an Assistant Professor in the Department of Neuroscience at Baylor College of Medicine. Jeff received his PhD in Neuroscience from Johns Hopkins University investigating the neural coding of 2D form in macaques with Steven Hsiao and Ed Connor. Jeff completed his postdoctoral fellowship in Neurology at Johns Hopkins Medical Institutions where he trained in non-invasive neuroimaging and brain stimulation techniques. Jeff has been at BCM since 2014 and his lab focuses on touch, cue combination, multisensory processing, and sensorimotor functions (www.yaulab.com).

Towards a computational account of somatotopic organization in human somatosensory cortex

Laura R. Edmondson[1,2]*, Hannes P. Saal[1,2]

[1] Department of Psychology, University of Sheffield, UK
[2] Sheffield Robotics, University of Sheffield, UK

Abstract

In primary somatosensory cortex (S1) the representation of the hand is organized somatotopically, with neighboring locations on the hand represented by adjacent cortical neurons. However, the size of cortical regions is not proportional to that of their physical counterparts, and specific regions, such as the fingertips, can be magnified beyond their physical size. What leads to this size variance in cortex? As previously proposed, the magnification of some regions may be due to the variance in receptor density across the hand, which increases from the palm towards the fingertip. However, electrophysiological recordings from monkeys and, more recently, advanced neuroimaging techniques in humans have demonstrated that the hand representation also changes depending on the nature of tactile input. Finally, although there are general similarities in mapping, exact representation varies across participants. This may reflect personal hand use, which alters the input received by cortex, but might also reflect random variation in the way the maps are initially established.

To investigate the contribution of these factors, we adapt a computational model that has been successful in simulating the development of visual retinotopic maps to the sense of touch. We employ a two-step process. First, we use a recently-developed large-scale simulation that reconstructs the responses of tactile afferent populations to create realistic peripheral response inputs. This model enables us to systematically vary the stimulus statistics and afferent density. Second, we model the resulting somatosensory representation using a self-organizing map algorithm. Our results demonstrate a complex relationship between receptor density, touch statistics and the predicted cortical mapping of digits. Furthermore, measures of the resulting cortical maps that are commonly used in fMRI experiments are differently affected by the input parameters and random noise; our results therefore pave the way for more robust and grounded analysis techniques.

References

Saal, H.P., Delhaye, B.P., Rayhaun, B.C., Bensmaia, S.J. (2017). Simulating tactile signals from the whole hand with millisecond precision. Proc Natl Acad Sci 114: E5693–E5702, 2017.

Short Biography

Laura Edmondson is a PhD student based in the Active Touch Lab at The University of Sheffield, under the supervision of Hannes Saal. She obtained a BSc in Psychology from the University of Manchester, followed by an MSc in Cognitive and Computational Neuroscience from the University of Sheffield. Her current work is using computational modelling to investigate the somatosensory representation of the hand.

SENSORIMOTOR CONTROL

Friday, August 31, 2018

09h00 – 09h40	**Stephen H. Scott** (Queens U) *Rapid sensory processing for voluntary motor control*	KEYNOTE
09h40 – 10h00	**Mike D. Rinderknecht** (ETH Zürich) *Rapid Assessment and Adaptive Therapy of Proprioceptive Hand Function After Stroke*	KEYNOTE
10h00 – 10h20	Andrea Sburlea (Graz U of Technology) *Exploring the representation of human grasps in EEG, EMG and kinematic signals*	E01T
10h20 – 10h50	Coffee	
10h50 – 11h20	**Derek Kamper** (North Carolina State U, U North Carolina) *Sensory representation of hand kinematics and kinetics in motor cortex*	KEYNOTE
11h20 – 11h40	Yuta Furukawa (Sophia U, SONY CSL) *Proprioceptive-auditory-motor integration in musicians and non-musicians*	E02T
11h40 – 12h00	Chris Versteeg (Northwestern U) *Divergent encoding of arm kinematics in the cuneate nucleus and primary somatosensory cortex*	E03T
12h00 – 12h20	**CSF Junior Award ceremony & closing words**	
12h30 – 14h30	Lunch	

Use of robots to study brain function and dysfunction

Stephen H. Scott[1]*

[1] Centre for Neuroscience Studies, Dept. of Biomedical and Molecular Sciences, Queen's University, Kingston, Canada

Abstract

There are several technologies that can be used to measure body movement, from accelerometers to video-based motor capture. However, robotic technologies, either grasped by a subject or directly attached to the limb, have an additional advantage in that they can apply loads to disturb body motion allowing us to probe properties of the motor system by observing how it responds to these unexpected disturbances. In the first half of my talk, I will highlight how we use robotic technology (guided by advanced control theory) to quantify how humans can generate complex goal-directed motor corrections in as little as 60ms, as well as complementary studies in non-human primates that demonstrate how frontoparietal circuits support this fast feedback process. In the second half of my talk, I will describe our clinical studies that use this same robotic platform to quantify sensory, motor and cognitive impairments associated with a variety of neurological injuries and disease. Integral to our approach is a suite of standardized behavioural tasks to quantify sensory, motor and cognitive impairments including automated scoring systems to compare subject performance to healthy controls considering factors such as age, sex and handedness. These robotic platforms provide an objective approach to develop novel pharmaceutical or therapeutic interventions, or to identify patterns or endotypes associated with a given disease.

References

Scott, S.H. (2016) A functional taxonomy of bottom-up sensory feedback processing for motor actions. Trends in Neuroscience 39:512-526.

Scott, S.H. and Dukelow, S.P. (2011) The potential of robots as a next-generation technology for clinical assessment of neurological disorders and upper limb therapy. Journal of Rehabilitation Research and Development 48(4):335-354.

Short Biography

Stephen Scott holds the GSK Chair in Neuroscience and is Professor in the Department of Biomedical and Molecular Sciences at Queen's University. He has formal training in engineering and physiology, and uses this knowledge to explore how the brain controls our ability to move and interact in the environment. A key to his research program is the development of robotic technology, called KINARM, that measures and modifies upper limb motor function. He co-founded and is Chief Scientific Officer of BKIN Technologies, which commercializes the KINARM robotic technology for basic and clinical research.

Rapid Assessment and Adaptive Therapy of Proprioceptive Hand Function After Stroke

Mike D. Rinderknecht[1]*, Olivier Lambercy[1], Joachim Liepert[2,3], Roger Gassert[1]

[1] Rehabilitation Engineering Laboratory, ETH Zurich
[2] Department of Neurorehabilitation, Kliniken Schmieder, Allensbach, Germany
[3] Lurija Institut, Konstanz, Germany

Abstract

Somatosensory hand function is essential for dexterous interaction with the environment and can be severely affected after neurological injuries such as stroke. In contrast to motor impairment and recovery, somatosensory function has received little attention, and clinical assessments still suffer from many shortcomings: non-standardized manual stimulus application resulting in poor inter- and intra-rater reliability, potential confounding factors such as motor and cognitive deficits, and ordinal scales leading to low sensitivity as well as floor and ceiling effects. There exist some robotic approaches addressing these limitations, however, many fail being integrated into clinical routine due to lengthy protocols, complex and expensive devices, or poor evaluation of psychometric properties.

Our aim is to develop, optimize, and clinically evaluate quantitative robotic assessments for somatosensation, which are sensitive, reliable, rapid to administer, and could be used in clinical routine. Here, we present the development of rapid proprioceptive assessments and discuss the evaluation of their reliability, validity, as well as clinical usability and utility. Furthermore, we present a concept of how such robotic assessments can be transformed into adaptive therapies targeting somatosensory deficits. These novel methodologies promise insights into the somatosensory recovery process, as well as individualized somatosensory therapy for a faster, more complete recovery.

References

Rinderknecht, M. D., et al. (2018). Rapid and Objective Assessment of Post-Stroke Deficits in Hand Proprioception. Journal of NeuroEngineering and Rehabilitation, 15(1), 47.

Rinderknecht, M. D., et al. (2016). Reliable and Rapid Robotic Assessment of Wrist Proprioception Using a Gauge Position Matching Paradigm. Frontiers in Human Neuroscience, 10.

Short Biography

Mike Domenik Rinderknecht worked on the development of robotic assessments and therapy concepts for somatosensory hand function after stroke during his Ph.D. and Postdoc at the Rehabilitation Engineering Laboratory (RELab) at ETH Zurich from 2013 to 2018. He received his B.Sc. and M.Sc. in Microengineering with a focus on robotics and autonomous systems as well as a Minor in Biomedical Technologies from the Ecole Polytechnique Fédérale de Lausanne (EPFL). As a visiting researcher at the Collaborative Haptics and Robotics in Medicine Laboratory (CHARM Lab) at Stanford University, he investigated learning in isometric and dynamic reaching for stroke rehabilitation. His research interests range from rehabilitation and medical robotics to sensorimotor learning and neuroscience.

Exploring the representation of human grasps in EEG, EMG and kinematic signals

Andreea I. Sburlea[1]*, Gernot R. Müller-Putz[1]

[1] Institute of Neural Engineering, Graz University of Technology, Austria

Abstract
The neural mechanisms of grasping have been investigated invasively in primates over decades [1]. However, from a noninvasive perspective, it remains unclear, how these neural mechanisms are reflected in human electroencephalographic (EEG) signals. Moreover, the relation between EEG signals and grasping covariates (such as joint angles, electromyography (EMG), object's shape, size, etc.), is not yet fully understood. In this exploratory study we address three questions: (1) Can EEG signals capture the differences between multiple types of grasps; (2) Which grasping covariate best explains how grasps are represented at the EEG level; (3) To what extent do grasping representations based on movement covariates and on EEG patterns resemble each other. To address these questions we recorded simultaneously EEG, EMG and kinematic data while 31 subjects performed multiple repetitions of 33 distinct grasping movements. In addition, we categorized the grasps based on the shape and size of the object, thumb's position relative to the palm, and type of grasp. We used representational similarity analysis [2] to explore the relation between grasping representations based on the patterns of the recording modalities and grasping categories, in three stages of the movement: hand pre-shaping, reach of final grasping position, and holding. Our findings show, at the group level, that grasping representations based on different movement covariates resemble the representation based on EEG patterns in different stages of the movement. During hand pre-shaping, the shape and size of the object is correlated with the EEG representation in the centro-parietal regions; while, during the finalization of the grasping movement and in the holding phase, the muscle representation shows moderate correlations with the EEG representation from the contralateral parietal regions. These findings contribute to the understanding of EEG correlates of grasping, and could inform the design of non-invasive neuroprosthetics and brain-computer interfaces with more natural control.

Acknowledgements
This work was supported by the ERC Consolidator Grant 681231 'Feel Your Reach'.

References
[1] Castiello, U. (2005). The neuroscience of grasping. Nature Reviews Neuroscience, 6(9), 726-736.

[2] Kriegeskorte, N., Mur, M., & Bandettini, P. (2008). Representational similarity analysis–connecting the branches of systems neuroscience. Frontiers in systems neuroscience, 2.

Short Biography
Andreea Ioana Sburlea received her Master's degree in Computer Science, with a specialization in Human-Machine Interaction, from University of Twente, Enschede, The Netherlands in 2013, and her PhD degree in Biomedical Engineering from University of Zaragoza, Spain, in 2016. She is currently a post-doctoral researcher at the Institute of Neural Engineering, Graz University of Technology, Austria. Her research interests are in motor neuroscience, machine learning and brain-computer interfaces.

Sensory feedback of movement/force characteristics in motor cortex during passive hand movement

Derek Kamper[1]*

[1] UNC/NC State Joint Department of Biomedical Engineering, University of North Carolina at Chapel Hill, Chapel Hill, NC and North Carolina State University, Raleigh, NC

Abstract

Proper movement execution requires appropriate feedforward and feedback signals, both of which are supported by the rich sensory feedback provided by the body. Given the importance of this sensory information, it is perhaps not surprising that neurons in primary motor cortex (M1), respond to sensory stimuli. Passive movements in non-human primates have been shown to elicit activity in M1[1]. Characterization of these relationships, however, have been limited by technical issues. For this study, an exoskeleton was developed to precisely control posture of the index finger and thumb in a rhesus macaque monkey in order to examine the response of neurons in M1 to sensory inputs[2]. The device was used to provide sinusoidal inputs to joint movements and fingertip force in a hand temporarily paralyzed through injection of botulinum toxin. Neural activity was recorded in M1 with an implanted electrode array during the imposed movement. The firing rate patterns were found to be strongly entrained to the sinusoidal stimulus. Additionally, more neurons were found to respond to joint movement than fingertip force and the phase-locking patterns to sinusoidal stimulus were much clearer and more stable for joint movement than for fingertip force. For the kinematic input, firing frequency increased with the displacement amplitude. These results suggest strong encoding of movement characteristics in M1 neurons without motor activity. This may prove important for brain machine interfaces.

References

[1] R. Lemon, J. Hanby, and R. Porter, "Relationship between the activity of precentral neurones during active and passive movements in conscious monkeys," *Proceedings of the Royal Society of London B: Biological Sciences,* vol. 194, no. 1116, pp. 341-373, 1976.

[2] Qian K, Dos Anjos LA, Balasubramanian K, Stilson K, Balcer C, Hatsopoulos NG, Kamper DG. Using monkey hand exoskeleton to explore finger passive joint movement response in primary motor cortex. *Proceedings of International Conference of the 36th EEE Engineering in Medicine and Biology Society.* Korea, 2017: 3624-3627.

Short Biography

Derek Kamper is an Associate Professor in the Joint Department of Biomedical Engineering at UNC-CH and NC State. He received a B.E. degree in Electrical Engineering from Dartmouth College and M.S. and Ph.D. degrees in Biomedical Engineering from Ohio State University. His work focuses on sensorimotor control of the hand, especially following neurological injury such as that resulting from stroke. These studies inform the development of new tools and techniques for rehabilitation, including soft hand exoskeletons, multi-user virtual reality environments, and electromyographically controlled games.

Proprioceptive-auditory-motor integration in musicians and non-musicians

Yuta Furukawa[1,2]*, Masato Hirano[2], Kazumasa Uehara[3], Yudai Kimoto[1,2], Takanori Oku[2], and Shinichi Furuya[1,2]

[1] Sophia University, Tokyo Japan
[2] Sony Computer Science Laboratories Inc. (SONY CSL), Tokyo Japan
[3] RIKEN Center for Brain Science (CBS)-TOYOTA Collaboration Center, Saitama, Japan

Abstract

Sensory afferent information plays an important role in dexterous motor control. Plastic changes of the sensory, motor and sensory-motor integration functions occur through musical training.[1] However, what remains unknown are impacts of long-term musical training on behavioral and neurophysiological mechanisms subserving these functions. Here, we conducted two studies to elucidate the proprioceptive-motor and auditory-motor integration mechanisms in musicians and non-musicians.

The study 1 consists of three distinct experiments. First, we recorded event-related potentials (ERP) using electroencephalogram (EEG) from the sensorimotor cortex induced by each of the digital nerve stimulation by electrical stimulation (ES) and the passive finger stimulation by a hand exo-skeleton robot (PS). Second, we assessed the effects of these sensory afferent inputs on the excitability of the primary motor cortex (M1) using the transcranial magnetic stimulation (TMS). Finally, we assessed a hand motor function by asking the participants to perform a fast tapping task. We found no significant differences in the amplitudes of ERP induced by the ES and the PS between the two groups. By contrast, we found that the short-afferent inhibition of the M1 excitability induced by the ES was reduced in the musicians compared with the non-musicians. The amount of the inhibition was significantly correlated with the finger tapping skill.

The study 2 consists of two experiments. First, we investigated how auditory information functionally modulates time-varying features of M1 in piano performance by using a closed-loop TMS system[2]. Second, we assessed auditory-motor skills responsible for feedback control by asking participants to play the piano accurately based on auditory feedback produced by themselves. We found that listening to piano tones during piano playing specifically facilitated the M1 excitability in a time-locked manner in the musicians but not in the non-musicians. The amount of facilitation induced by auditory inputs was significantly correlated with the control of force production in musical performance.

These results indicate that the specialized sensory-motor integration in musicians subserves dexterous hand motor control.

References

[1] Sibylle C Herholz., and Robert J. Zatorre. 2012. “Musical Training as a Framework for Brain Plasticity: Behavior, Function, and Structure.” Neuron 76 (3).

[2] Furuya, S., Furukawa, Y., Uehara, K. & Oku, T. Probing sensorimotor integration during musical performance. Ann. N. Y. Acad. Sci. 0, 1–8 (2018).

Short Biography

2018-: PhD student, Graduate School of Science and Technology, Sophia University, Tokyo, Japan (Research Fellow of Japan Society for the Promotion of Science)
2016-2018: Master of Engineering, Sophia University, Tokyo, Japan
2012-2016: Bachelor of Science, Sophia University, Tokyo, Japan

Divergent encoding of arm kinematics in the cuneate nucleus and primary somatosensory cortex

Chris Versteeg[1]*, Raeed Chowdhury[1], Tucker Tomlinson[2], Lee E. Miller[2,3,4]

[1] Dept. of Biomedical Engineering, Northwestern University, Chicago IL
[2] Dept. of Physiology, Northwestern University, Chicago IL
[3] Physical Medicine and Rehabilitation, Northwestern University and Rehabitation Institute of Chicago, Chicago IL.
[4] Shirley Ryan AbilityLab, Chicago IL

Abstract

Single neurons in the cuneate nucleus (CN), the initial site of afferent somatosensory information convergence in the CNS, have never been recorded during active behavior. To understand how the motor system uses feedback to control arm movements, we must first understand how sensory information is transformed as it moves centrally. We present novel data which show that the encoding of arm kinematics in the cuneate nucleus is quite different from the representation in the cortex. Limb state is represented similarly in somatosensory cortex (S1), whether the result of voluntary reach movement or an unexpected perturbation applied to the hand. In contrast, kinematically-similar active and passive movements result in different responses in CN. The source of differences in CN, and subsequent processing that eliminates them, are unknown.

We implanted Utah multi-electrode arrays (MEAs) chronically in CN of two monkeys. One had an MEA in area 2 of S1. These animals were trained to control a cursor by making reaching movements while grasping a robotic manipulandum. We used the robot to apply forces to the hand that generated endpoint kinematics similar to those of reaching.

We recorded from single neurons in CN and area 2 and fit Generalized Linear Models to neural firing as a function of endpoint kinematics. There was a significant bias in the CN preferred directions (PDs) in both monkeys, but none in the area 2 neurons. To confirm these biases were not an artifact of the center-out task, we also fit GLMS to data from a random-target task. CN PDs computed under these conditions were also biased, showing the encoding of arm kinematics in CN is dependent on movement context, a dependence that is largely eliminated at the level of S1. This knowledge has important implications for understanding how spinal and transcortical loops are used to control movement.

Short Biography

Chris Versteeg obtained his B.S. in Biomedical Engineering with a minor in Computer Science from Georgia Institute of Technology in 2015, doing undergraduate research in the lab of Dr. Lena Ting, modeling kinematic goals that shape postural response strategies. At GT, he recieved the Computational Neuroscience Training Grant. He began Ph.D. work in 2015 at Northwestern University, where he joined the lab of Dr. Lee E. Miller and began work to understand the somatosensory processing occurring near the periphery. He was accepted onto the Biomedical Data Driven Discovery training grant from 2016-2018, and was recently awarded an NRSA F31.

POSTERS

ABSTRACTS

NEUROPHYSIOLOGY

Sensory signal processing during a delayed-grasp task in the primate brain

Daniela Buchwald[1,2]*, Benjamin Dann[1], Hans Scherberger[1,2]

[1] Neurobiology Laboratory, German Primate Center (DPZ), Göttingen, Germany
[2] Faculty of Biology and Psychology, Georg-August-Universität Göttingen, Germany

Abstract

An important task for animals is the correct interpretation of sensory information in order to interact with their surroundings. The identification of objects and physical properties using different senses is particularly important when an object needs to be grasped precisely. For many brain areas evidence exists about their role in object recognition, grasp preparation and execution. However, how these areas interact and whether activity changes when objects are perceived with different senses has not been extensively studied.

To this end, we trained rhesus macaques to perform two variants of a delayed-grasping task, in which they had to lift objects that were either only seen or only felt beforehand. We recorded spiking activity from four different brain areas in parallel that are known to be involved in the preparation and execution of grasping movements and visual and tactile perception (premotor cortex F5, primary motor cortex M1, anterior intraparietal area AIP, and somatosensory cortex S1).

Preliminary analysis revealed differences in spiking activity during grasp preparation between visually and tactually guided trials. For visual trials, neurons in the grasp-related areas showed, as expected, strong, prolonged, and object selective preparatory activity. Neural modulation during the delay period was much weaker for tactile trials and disappeared almost completely before grasp execution. In primary somatosensory cortex, we observed no memory effect during visual trials and only a weak memory effect during tactile trials, which also disappeared before grasp execution. The explanation that objects are simply not memorized properly was not supported by behavioral analysis revealing that grasps were still executed highly efficiently. This suggests that tactile object information, in contrast to visual one, is not memorized by increased firing rate during the delay period. Another explanation would be that this information is located elsewhere and arrives in the fronto-parietal grasp areas only shortly before movement execution.

Short Biography

Daniela Buchwald is a PhD student at the Neurobiology Laboratory of the German Primate Center in Göttingen, in the field of brain-computer interfaces, investigating tactile information processing in the brain and how the brain plans and executes prehensile movements when graspable objects are perceived with different senses.

She holds a Bachelor of Science in Biology and Master of Science in Computer Science, both from the University of Göttingen. In her master thesis, she investigated how object recognition can be improved using 3D images of the surrounding.

Interests include brain-computer interfaces, the sense of touch, robotics, and primate electrophysiology.

Comparison of surround inhibition on the fingertips of human and non-human primates

Anne-Dominique Gindrat[1]*, Camille Roux[2], Eric Schmidlin[2], Eric M. Rouiller[2], Arko Ghosh[3]

[1] Neurobiology Laboratory, Deutsches Primatenzentrum GmbH, Göttingen, Germany
[2] Department of Medicine / Physiology, University of Fribourg, Switzerland
[3] Cognitive Psychology Unit, Institute of Psychology, Leiden University, The Netherlands

Abstract

According to the idea of 'surround inhibition', sensory stimulation excites the corresponding cortical circuits while it inhibits the neighboring cortical circuits. This feature of cortical processing is very well addressed in the visual and auditory systems of humans and non-human primates, but it is not well explored in the somatosensory system. We have already helped fill this gap by showing signatures of surround inhibition for the hand when delivering simultaneous tactile stimulations on the thumb and index finger tips in humans [1]. Essentially, the amplitude of the neuronal responses is smaller for the simultaneous stimulation than the linear sum of the amplitudes obtained from the individual stimulations. Here we report a comparative analysis of surround inhibition in humans and non-human primates. We delivered identical sets of tactile stimulations on the thumb and index finger tips in anesthetized monkeys and resting humans, and used scalp electroencephalography (EEG) to measure the associated cortical responses to touch.

Firstly, we found that tactile stimulation of the thumb and index finger resulted in clear somatosensory evoked potentials in both the species, but as anticipated the signal latency measured in monkeys was shorter than in humans. Secondly, the signature of surround inhibition was observed in all monkeys and humans, with considerable inter-individual variability.

Finally, the measured inhibition was present through the primary and secondary stages of cortical sensory processes in both humans and monkeys. Our work provides a comprehensive empirical overview on how tactile inputs are processed in large neuronal populations, and elaborates on how a common computational principle is implemented across species to sense and control the hand.

Reference

[1] Gindrat, A.-D.*, Chytiris, M.*, Balerna, M.*, Rouiller, E.M., Ghosh, A. (2015). Use-Dependent Cortical Processing from Fingertips in Touchscreen Phone Users. Current Biology, 25(1): 1-8.

Short Biography

I got a PhD in Neurosciences in 2015 (Laboratory of Prof. E. Rouiller, University of Fribourg). I have been studying the human and non-human primate sensorimotor system using EEG.

Since November 2015, I have been working as a postdoc in the Neurobiology Laboratory of Prof. H. Scherberger at the Deutsches Primatenzentrum (Göttingen, Germany). I am investigating the causal contribution of three cortical areas of the primate hand grasping network (F5, M1, AIP) in planning and executing hand grasping movements in behaving macaque monkeys. For that, I am using the emerging approach of optogenetics that has recently been established in primates.

Shape-elasticity tactile confound

Jessica Hartcher-O'Brien*[1], Benoni Edin[2], Vincent Hayward[3]

[1] Industrial Design Engineering, Delft University of Technology, Netherlands
[2] Department of Integrative Medical Biology, Umeå University, Umeå, Sweden
[3] School of Advanced Study, University of London

Abstract

Recent studies, [1, 2], suggest that the mechanics of fingertip-object interactions can provide insight into the functional link between the hand, the brain, and our haptic perception of the world. When two convex objects, a finger $'f'$ and a surface $'s'$, come into Hertzian contact, the respective elastic moduli E_f, and E_s, the radii of curvature, R_f and R_s, the pressing force, f, the deflection, d, and the size of the contact area, a, of these bodies are interrelated. If we assume that the finger and the surface are incompressible, and that the finger is a homogeneous, isotropic sphere, (its behaviour does not deviate much from that theory [3]), then it can be shown that E_s and R_s play interchangeable roles in the relationship that link a to f. If a is an adequate representation of the mechanical state of the finger, then two behavioural hypotheses follow, namely:

There exists perceptual metamers of compliance, i.e, physically distinct stimuli give rise to the same perception because R_s and E_s are confounds.

An object's surface curvature and compliance are increasingly confused with increased E_s.

Our findings suggest that, indeed, the interaction between a fingertip and a convex surface produces a perceptual outcome equivalent to decreasing E_s, while the interaction between the fingertip and a concave surface creates a perceptual estimate of surface compliance equivalent to an increase in E_s.

A low or high E_s both yield a metameric response, however, as predicted, for low E_s, the effect diminishes significantly. These results, for the first time, provide evidence of a tactile perceptual metamer that can be predicted basic mechanics. The implications of this finding for perceiving and rendering object properties are discussed with respect to the functional link between the hand, brain and environment.

References

[1] A. V. Terekhov and V. Hayward. The brain uses extrasomatic information to estimate limb displacement. Proceedings of the Royal Society of London, B, 282(1814):20151661, 2015.

[2] Moscatelli, A., Bianchi, M., Serio, A., Terekhov, A., Hayward, V., Ernst, M. O., Bicchi, A. 2016. The Change in Fingertip Contact Area as a Novel Proprioceptive Cue, Current Biology. 26(9):1159-1163.

[3] M. Wiertlewski and V. Hayward. Mechanical behavior of the fingertip in the range of frequencies and displacements relevant to touch. Journal of Biomechanics, 45(11):1869Ð1874, 2012.

Short Biography

Jess Hartcher-O'Brien received her PhD in Experimental Psychology from the University of Oxford in 2012, advised by Charles Spence. She spent two years as a visiting student at the Max Planck Institute for Biological Cybernetics, Tuebingen, Germany in the Perception and Action group led by Marc O. Ernst. In 2013 she won a Fyssen Foundation fellowship for independent post-doctoral research at the Ecole Normale Supérieure, Paris France in Malika Auvray's group. As a post-doctoral researcher, she worked at the Université Pierre et Marie Curie with Vincent Hayward under the auspices EU funded projects, Wearhap and ERC PATCH (2015-2016). She currently holds a Delft Technology Fellowship assistant professorship in Haptics in the Department of Industrial Design Engineering at TUD.

Spiking pattern determines vibrotactile frequency perception independent of activated receptor type

Ingvars Birznieks[1,2,4], Sarah McIntyre[2,4,5], Hanna Nilsson[2,5], Saad Nagi[3,5], Richard Vickery[1,2]*

[1] School of Medical Sciences, UNSW Sydney, Australia.
[2] Neuroscience Research Australia, Sydney, Australia.
[3] School of Medicine, Western Sydney University, Australia.
[4] Biomedical Engineering and Neuroscience, MARCS institute, Sydney, Australia.
[5] Center for Social and Affective Neuroscience, Linköping University, Sweden.

Abstract

Vibrotactile stimuli are generally considered to evoke two qualitatively distinctive sensations: flutter (frequencies < 60 Hz) and vibratory hum (frequencies > 60 Hz). For sinusoidal stimuli in the glabrous skin these frequency ranges are subserved by Meissner and Pacinian afferents respectively, which may engage distinct neural processing pathways or channels often referred to as Pacinian and non-Pacinian. We used brief pulsatile mechanical stimuli, 3 µm in amplitude, that selectively activated only Pacinian afferents, to show that spike trains in Pacinian afferents can readily induce a vibratory percept with the same frequency attributes as sinusoidal stimuli of the flutter-frequency range. Furthermore, the ability of subjects (n = 12) to discriminate these flutter-range frequencies was equally good, regardless of whether they were signalled by predominantly Meissner afferents, or solely by Pacinian afferents. This indicates that spiking pattern rather than activated receptor type determines vibrotactile frequency perception. This further suggests a common central processing mechanism for vibrotactile information, which may underlie recent reports of convergence in primary somatosensory cortex of signals originating from these afferent types (Carter et al., 2014; Saal et al., 2015), as well as explaining the constancy of vibrotactile frequency perception across skin regions innervated by different afferent types.

References

Carter, A.W., Chen, S.C., Lovell, N.H., Vickery, R.M. and Morley, J.W. (2014). Convergence across tactile afferent types in primary and secondary somatosensory cortices. PLoS One 9(9): e107617.

Saal, H.P., Harvey M.A. and Bensmaia S.J. (2015). Rate and timing of cortical responses driven by separate sensory channels. eLife 4: e10450.

Short Biography

Richard Vickery is a neurophysiologist with active research in the fields of sensory neuroscience, neural coding, and prosthetics. Richard has used a range of electrophysiological techniques in vivo and in vitro to study questions of synaptic transmission and information encoding. In recent years his main focus has been studies in the human sense of touch combining psychophysical and microneurographic approaches. Richard is also an active educator with research and practice interests in education around the engagement of students, especially in learning fundamental biomedical concepts.

Primary somatosensory cortex and Hebbian associative learning: a novel cross-modal Paired Associative Stimulation (PAS) protocol

Giacomo Guidali[1]*, Agnese Zazio[2,3], Ottavia Maddaluno[3], Carlo Miniussi[2,4] & Nadia Bolognini[3,5]

[1] School of Medicine and Surgery, University of Milano-Bicocca, Monza, Italy.
[2] Cognitive Neuroscience Section, Saint John of God Clinical Research Center, Brescia, Italy.
[3] Department of Psychology, University of Milano-Bicocca, Milano, Italy.
[4] CIMeC - Center for Mind/Brain Sciences, University of Trento, Rovereto, Italy.
[5] Laboratory of Neuropsychology, IRCCS Istituto Auxologico Italiano, Milano, Italy.

Abstract

An increasing number of evidence suggests the existence of a Tactile Mirror System in the human brain: the same cortical network implicated in tactile perception, which comprises the primary somatosensory cortex (S1), also responds to the mere observation of tactile events. It has been suggested that such cross-modal, mirror-like, responses of S1 may arise from Hebbian associative plasticity: the contingency of seeing a touch and the feeling of a tactile sensation on one's own body may reinforce synapses between visual and somatosensory neurons.

We tested this hypothesis introducing a novel cross-modal Paired Associative Stimulation (PAS) protocol. In the cross-modal PAS, a visual stimulus depicting a hand being touched is repeatedly presented, paired with a Transcranial Magnetic Stimulation (TMS) pulse over S1.

In experiment 1, we tested both the temporal and the cortical specificity of the plasticity effects induced by the protocol. Results showed that cross-modal PAS was effective in eliciting Hebbian associative plasticity, modulating subjects' tactile acuity (measured with a 2-Point Discrimination Task) selectively when the Inter-Stimulus Interval (ISI) between the two paired stimulations was 20 ms and the TMS pulse is delivered over S1. In experiment 2, we looked for evidence for a selectivity of the visual responsiveness of S1 and the role of expectancy during the cross-modal PAS. We also aimed to uncover possible neurophysiological changes in S1 by pairing the measurement of subjects' tactile acuity with the recording of Somatosensory-Evoked Potentials (SEPs).

To sum up, our study provides novel insight of the visual activity of S1, showing that our cross-modal PAS can induce plastic changes in S1, in line with an Hebbian associative learning rule. This evidence also offers new insights on the neural substrates of the Tactile Mirror System and, in a broader perspective, of early visuo-tactile interactions in the primary (low-level) stages of sensory processing.

References

Catmur, C., Press, C., & Heyes, C. (2016). Mirror Neurons from Associative Learning. In The Wiley Handbook on the Cognitive Neuroscience of Learning (pp. 1–45).

Wolters, A., Schmidt, A., Schramm, A., Zeller, D., Naumann, M., Kunesch, E., & Classen, J. (2005). Timing-dependent plasticity in human primary somatosensory cortex. The Journal of Physiology, 565(3), 1039–1052.

Short Biography

Giacomo Guidali is a psychologist and a PhD student in Neuroscience at the School of Medicine and Surgery of the University of Milano-Bicocca under the supervision of Prof. Nadia Bolognini. He is graduated with honours at University of Milano-Bicocca in Clinical, Developmental and Neuropsychology (MCs). After graduation, He completed his one-year internship in the Department of Psychology of the University of Milano-Bicocca and in the Laboratory of Neuropsychology of the IRCCS-Istituto Auxologico Italiano. His main research interest concerns the use of non-invasive brain stimulation techniques to investigate the functioning of cortical networks and the neural bases of cross-modal integration processes.

COGNITIVE NEUROSCIENCE

Body image develops according to somatosensory-motor influences: a cross-sectional study with graph network analysis

T. K. F. Cruz[1,2]*, D. O. Souto[1,2], A. Júlio-Costa[2], P. L. B. Fontes[2,3], V. G. Haase[1,2]

[1] Graduate Program in Neuroscience – Universidade Federal de Minas Gerais, Brazil
[2] Laboratório de Neuropsicologia do Deselvolvimento (LND) - Universidade Federal de Minas Gerais, Belo Horizonte, Brazil
[3] Department of Physical Therapy – Pontifícia Universidade Católica de Minas Gerais, Brazil

Abstract

This study aims to explore the influence of body schema and body structural description on the development of body image. To test this hypothesis, a sample of 204 typical developed children between 4-12 years old and 45 hemiplegic children between 7-15 years old were assessed on general intelligence and body-semantic knowledge (body image). For a better comprehension of the development of the sensory-motor processes on semantic-lexical knowledge of the body parts, typical developed children group were subdivided into three age groups: 4-6 years (n=69), 7-9 years (n=59), and 10-12 years (n=76). Graph network analysis and variance analysis were used to investigate the development of body semantic-knowledge. Comparisons among typical developed children age groups showed that: (1) the parts of the body that receive more sensory stimuli (such as mouth, eyes, nose and ears) and are used to explore the environment (such as arms, hands, legs and feet) were learned first and were present since 4-6 years old; (2) with the subsequent refinement of position matching ability and motor control by children (providing more tactile, kinesthetic, proprioceptive and vestibular experiences), the lexical-semantic learning of the joints is favored at 7-9 years old; and, (3) visuospatial information also influences the acquisition of semantic-lexical knowledge of the body, thus, learning the dorsal and internal organ structures occurs later during child development (after ten years old). However, in this sample, hemiplegic group presented differences from this pattern and did not learn the joints, dorsal structures and internal organs. Considering the disturbances of the sensation and perception present in cerebral palsy, our results seems to imply that development of body image is based on visual and proprioceptive feedback (i.e., relies on body schema and body structural description). This study supports the hypothesis that body schema and body structural description interactions influence development of body image.

References

[1] Auclair, L., and Jambaqué, I. (2015). Lexical-semantic body knowledge in 5- to 11-year-old children: how spatial body representation influences body semantics. Child Neuropsychology, 21(4): 451-64.

[2] Fontes, P. L. B., Cruz, T. K. F., Souto, D. O., Moura, R. and Haase, V. G. (2016). Body representation in children with hemiplegic cerebral palsy. Child Neuropsychology, 10, 1-26.

Short Biography

Thalita Cruz has a Bachelor of Physical Therapy and obtained a Master's degree in Neuroscience with studies in neuropsychology and clinical psychology at the Universidade Federal de Minas Gerais (Brazil) in 2016. She is currently a PhD student with Dr. Vitor Haase. Her research interests are body perception development, neuroplasticity, brain damaged populations, somatosensory system and motor function.

The distinct roles of sensorimotor rhythms in the perception and selection of tool use: An EEG and virtual reality study

Francois Foerster[1]*, Jeremy Goslin[1]

[1] School of Psychology, University of Plymouth, UK

Abstract

How the brain stores and selects motor programs to execute tool utilization has been an important research topic during the last decade. Sensorimotor μ oscillations (8-13 Hz) appear to reflect objects' affordances[1], whereas β oscillations (14-30 Hz) have been associated with the retrieval of semantic objects' knowledge[2]. The literature has provided detailed models of action selection, but how the resulting decision of cortico-subcortical operations might be represented in the motor system remains unclear. We have investigated the role of such EEG sensorimotor rhythms in the perception of learned object affordances and the selection of utilization of novel objects. Using a go/no-go paradigm, participants performed two possible tool utilizations (i.e. lighting up a candle and opening a box) with two different objects in virtual reality. Thirty-seven EEG recordings were analysed in the time-frequency domain using a cluster randomization process. In one hand, we found that perceiving an object associated with two utilizations ("dual tool") reduced the desynchronization of sensorimotor neurons on the β frequency band, in comparison with an object associated with a unique use ("single tool"). We also found a reduced μ 8-10 Hz synchronization, a reduced μ 10-12 Hz desynchronization1 and a reduced left premotor N1 ERP component for the dual tool. These results demonstrate that learning how to manipulate a novel tool modulate the μ and β cortical oscillations during object perception, neural signatures of sensorimotor integration.

On the other hand, selecting an appropriate utilization with the dual tool reduced the δ 1-4 Hz synchronization and reduced the late sensorimotor ERPs, compared to selecting the same utilization with the single tool. Hence, the selection of learned tool utilization appears specifically encoded in fast δ oscillations. In contrast with the literature, we propose that the perception and selection of learned object affordances are based on distinct oscillatory mechanisms.

References

[1] Proverbio, A. M. (2012). Tool perception suppresses 10-12Hz mu rhythm of EEG over the somatosensory area. Biological Psychology, 91(1), 1–7.

[2] van Elk, M., van Schie, H. T., van den Heuvel, R., & Bekkering, H. (2010). Semantics in the motor system: motor-cortical Beta oscillations reflect semantic knowledge of end-postures for object use. Frontiers in Human Neuroscience, 4(8), 1–12.

Short Biography

Francois is a PhD student in cognitive neuroscience at the university of Plymouth, supervised by Jeremy Goslin. Using EEG and virtual reality, the aim of his thesis is to evaluate the activation of learned motor and semantic properties of novel objects for different manipulation (e.g. moving or using tools). Previously, Francois studied cognitive science at the Grenoble Institute of Technology (France), accompanied with some research in human-robot interaction.

Perceptual distortion of the own body size by changes of its cortical somatosensory map: An rTMS study

Serena Giurgola[1]*, Alberto Pisoni[2], Giuseppe Vallar[2,3], Angelo Maravita[2] & Nadia Bolognini[2,3]

[1] School of Medicine and Surgery, University of Milano-Bicocca, Milan, Italy
[2] Department of Psychology & NeuroMI – Milan Center for Neuroscience, University of Milano-Bicocca, Milan, Italy
[3] Laboratory of Neuropsychology, IRCCS Istituto Auxologico Italiano, Milan, Italy

Abstract

Tactile information affect the abstract representations of one's own body, including the knowledge of its size [1]: perceptual body size distortions can be induced by altering incoming tactile inputs by means of peripheral nerve block or anaesthesia [2]. This evidence indicates that the perceived size of our own body involves plastic changes within the primary somatosensory cortex (S1). To verify this hypothesis, low-frequency (1 Hz) repetitive transcranial magnetic stimulation (rTMS) was used to induce short-term plastic changes of S1 hand representation, assessing perceptual distortions of the own hand size with the Hand Size Task (HST). In the HST, pictures of the participants' own left and right hands were scaled to be smaller/bigger than their real hand; participants had to judge whether the viewed hand matched or not the own hand size, which was out-of-view. The 2-Point Discrimination Task (2PDT) was used as control task. Both tasks were administered before and after rTMS over the right and left S1 (Experiments 1 & 2). Then, rTMS was the applied over the right and left inferior parietal lobule (IPL, Experiment 3), while in the last study (Experiment 4) the somatopic selectivity of bodily perceptual distortion by S1-rTMS was assessed by presenting pictures of either the hand and the foot during the HST.
Results showed that rTMS targeting the hand representation S1 of both hemispheres lead to an overestimation of the perceived size of the own right and left hands, while the perceived size of the foot was unaltered. No changes of the perceived size of the own hand were induced by rTMS over IPL of both hemispheres.
This evidence highlights the perceptual consequences on the body metric representation induced by short-term plastic reorganization of the cortical somatosensory maps, which may give rise to a sort of macro-somatoagnosia.

References

[1] Vallar, G. and Rode, G. (2009). Commentary on Bonnier P. L'aschématie. Rev Neurol (Paris) 1905;13:605–9. Epilepsy & Behavior, 16(3): 397–400.

[2] Gandevia, S.C. and Phegan, C.M.L. (1999). Perceptual distortions of the human body image produced by local anaesthesia, pain and cutaneous stimulation. Journal of Physiology, 514(2): 609–616.

Short Biography

Serena Giurgola earned her Master's degree in Neuroscience & Neuropsychological Rehabilitation (University of Bologna, IT) in 2014, taking part in a research project investigating the cognitive and neural mechanisms of bodily self-consciousness and ownership in healthy and neurological individuals. In 2015, she joined the ImpAct Team (INSERM, Lyon, FR) directed by Prof. A. Farné, exploring multisensory perception in stroke patients with spatial hemineglect. Since 2016, she is PhD student in Clinical Neuroscience (University of Milano-Bicocca, IT), under the supervision of Prof. N. Bolognini, focusing her research activity on the study of multisensory brain and body plasticity with non-invasive brain stimulation.

Neural correlates of hand augmentation

Paulina Kieliba[1]*, Dominic Stirling[1], Tamar R Makin[1]

[1] Institute of Cognitive Neuroscience, University College London, 17 Queen Square, London

Abstract

In the recent years there has been increased interest in augmentative technologies that extend the physical and cognitive abilities of able-bodied individuals. Supernumerary robotic fingers are an example of such technology, designed to allow the user to single-handedly perform normally bimanual tasks. However, these new devices introduce various theoretical and practical challenges: (i) what resources could one's brain employ to control a body part that has never been there before? (ii) what are the risks and benefits of modulating one's body representation in order to support and enhance supernumerary robotic fingers usage? Here, using human somatosensory cortex as a model, we investigate neural correlates of hand augmentation. We train healthy able-bodied participants to use a supernumerary robotic finger over the course of one week. During the training participants have to complete a set of normally bimanual tasks from daily life using only the augmented hand. A separate group of controls wears the robotic finger for the same duration of time but without using it. We use pre- to post-comparison measures to assess the outcomes of the training and see whether hand augmentation affects the representation of body in the brain. We track neuronal changes in the somatotopic hand representation using 3T fMRI (focusing on representational similarity analysis and functional connectivity) and a set of well-defined behavioural tasks (e.g. force enslavement, motor confusion). By studying the neural correlates of hand augmentation, we hope to probe the boundaries of brain plasticity and provide the community with a brand-new model for examining the adult brain's ability to dynamically update body representations based on new experiences

References

Prattichizzo, D., Malvezzi, M. and Hussain, I. (2014) The Sixth-Finger: A modular extra-finger to enhance human hand capabilities. In Proc. IEEE Int. Symp. in Robot and Human Interactive Communication, 993-998.

Ejaz, N., Hamada, M. and Diedrichsen, J. O. R. (2015). Hand use predicts the structure of representations in sensorimotor cortex. Nature Neuroscience, 8(7):1034-40.

Short Biography

Paulina Kieliba is a PhD student at the Institute of Cognitive Neuroscience, University College London. Her research focuses on studying the changes in the sensorimotor systems associated with the usage of extra robotic fingers both in healthy participants and in amputees.

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

Sanne Kikkert[1,2]*, Melvin Mezue[2], Jacinta O'Shea[2], David Henderson-Slater[3], Heidi Johansen-Berg[2], Irene Tracey[2], Tamar Makin[2,4]

[1] Department of Health Sciences and Technology, ETH Zürich, Switzerland.
[2] Nuffield Department of Clinical Neurosciences, University of Oxford, United Kingdom.
[3] Oxford Centre for Enablement, Nuffield Orthopaedic Centre, United Kingdom.
[4] Institute of Cognitive Neuroscience, University College London, United Kingdom.

Abstract

After arm amputation individuals often experience painful sensations of their missing limb (phantom limb pain, PLP). PLP is difficult to treat, in part due to an incomplete understanding of its underlying mechanisms. We previously showed that chronic PLP positively associates with maintained activity in the primary sensorimotor (S1/M1) missing hand cortex. Here we made use of this preserved missing hand representation and designed a new PLP treatment.

To influence information processing of peripheral missing hand signals that were previously implicated with PLP, we instructed 15 upper-limb amputees suffering from chronic PLP to execute phantom hand movements during a single 20min session of non-invasive brain stimulation. We applied anodal (1mA) transcranial direct current stimulation (tDCS) over the missing hand S1/M1 cortex (hereafter intervention stimulation) in a within-participants, double-blind, counterbalanced, and sham-controlled design. We obtained PLP ratings and functional MRI scans prior to, during, and post brain stimulation.

While PLP was significantly increased in the sham condition immediately after brain stimulation, task-concurrent intervention stimulation averted this PLP increase. Importantly, we observed significant PLP relief 90min following task-concurrent intervention stimulation, with effects lasting at least one week. No lasting PLP changes were observed in the sham condition. PLP relief associated with reduced phantom hand movement activity in the S1/M1 missing hand cortex after stimulation. Importantly, reduced activity in the S1/M1 missing hand cortex was only observed after stimulation, suggesting it may be a correlate of PLP relief rather than its driver. Crucially, activity changes during intervention stimulation in several pain-related areas, e.g. the insula and secondary somatosensory cortex, predicted both the subsequent reduction in S1/M1 activity and PLP relief.

Together, our findings suggest that processing in S1/M1, an area often implicated in PLP and other chronic pain conditions, may be a correlate of the pain sensation rather than its cause.

Short Biography

In 2018 Sanne Kikkert completed her PhD at the University of Oxford (United Kingdom) under the supervision of Dr. Tamar Makin. She is currently a postdoctoral associate at the Neural Control of Movement lab at ETH Zürich, advised by Prof. Nicole Wenderoth. She uses neuroimaging techniques to study how organisation in the somatosensory processing stream may change of persist following major sensory input loss.

Are prosthetic limbs represented as hands or tools? An fMRI study

Roni O Maimon-Mor[1,2]*, Tamar R Makin[1,2]

[1] Institute of Cognitive Neuroscience, University College London, London, UK
[2] FMRIB Centre, Nuffield Department of Clinical Neuroscience, University of Oxford, Oxford, UK

Abstract

When using a prosthetic limb, the brain may utilize one of two existing frameworks to represent and control the novel object: the visuomotor body network or the tool-use network. Images of prosthetic arms have recently been shown to activate hand-selective areas in the occipitotemporal cortex (OTC) in prosthesis users. This area is also known to be activated by hand-held tools. Here, we wished to determine whether prosthesis representation resembles that of upper-limbs, in terms of pattern structure, or whether instead it resembles tool representation. Individuals with acquired or congenital upper limb loss (hereafter one-handers) were tested to investigate how limb loss and hand-substitution (wearing a prosthesis) shape categorical reorganisation in OTC. We used Representational Similarity Analysis of functional MRI data from 32 one-handers and 24 two-handed controls. Participants viewed images of upper-limbs (lateralised to match the missing side of one-handers), tools, others' prostheses, and one-handers' own prosthesis in an event-related design. A region of interest in OTC was independently localised by contrasting images of headless-bodies and objects. Experience-dependent reorganisation was found in one-handers' prosthesis representation, though our analysis revealed a more complex reality than originally expected. For both congenital and acquired one-handers, those who use a prosthesis more in daily life, show greater representation of others' prostheses as an independent category, distinct from hands and tools. However, when observing their own prosthesis, congenital and acquired one-handers prosthesis representation differed, with congenitals, but no acquired amputees, displaying a prosthesis representation more similar to upper limbs than tools. This is consistent with a recent behavioral study suggesting a less rigid categorisation of upper limbs in individuals who lost their hand earlier in life. Together, our results provide evidence of an adaptable use-dependent categorical visual representation, while challenging current views of prosthesis "embodiment".

References

van den Heiligenberg, F. M., Orlov, T., Macdonald, S. N., Duff, E. P., Henderson Slater, D., Beckmann, C. F., Johansen-Berg H., Culham J.C. and Makin, T. R. (2018). Artificial limb representation in amputees. Brain [Epub ahead of print].

Bracci, S. and Peelen, M. V. (2013). Body and object effectors: the organization of object representations in high-level visual cortex reflects body–object interactions. Journal of Neuroscience, 33(46), 18247-18258.

Short Biography

Roni is a Clinical Neuroscience PhD student at Oxford University and a member of the London Plasticity lab. In her research she aims to integrate tools from different disciplines (cognitive psychology, neuroimaging, rehabilitation, computational neuroscience), to investigate various aspects of prosthesis representation and control in hopes to better understand the issue of low prosthesis usage in individuals with congenital and acquired limb loss.

Neural dynamics of tool-extended sensing

Luke E. Miller[1]*, Cécile Fabio[1], Romeo Salemme[1], Vincent Hayward[2], Alessandro Farnè[1]

[1] INSERM U1028 ImpAct Team, France
[2] Université Pierre et Marie Curie, France

Abstract

Natural selection shaped the human hand and its corresponding neural machinery to facilitate the use of tools to manipulate the environment. The majority of scientific research on tool use to date has focused almost exclusively on the motor side, even though tools convey sensory information whenever they contact a surface. We recently investigated whether tools can extend sensory processing beyond the body (Miller et al., under review), a phenomenon we termed tool-extended sensing. In a series of behavioural experiments, we demonstrated that users can localise impacts on the surface of a hand-held rod with remarkable accuracy. Further experiments suggested that impact-location is initially encoded by the rod's vibratory response and then re-encoded by spiking patterns of Pacinian mechanoreceptors in the hand. The present study sought to investigate the cortical dynamics of this phenomenon. We used electroencephalography to measure neural oscillations while participants localised impacts on a hand-held rod. Participants performed a sensory working memory task, where they determined whether the two impacts (separated by 2000–2500 ms) occurred at the same or different location. We focused our initial analysis on the first impact and the information maintenance period. We observed an early sensory-driven response in the theta band (4–8 Hz; 50–300 ms post-contact), which was isolated to channels directly over contralateral somato-motor cortex. This was followed by a significant desynchronization in the alpha band (8–12 Hz; 400–700 ms) over contralateral posterior parietal cortex, which was likely related to the perceptual processing of impact location. Finally, we found that location information was maintained by a sustained synchronisation in the beta band (15–25 Hz; 800–1400 ms) over contralateral parietal channels. These results represent the initial steps towards understanding how tool-extended sensing emerges from the functional coupling between technological, biomechanical, and neural levels of information processing.

References

Miller, LE., Montroni, L., Kuhn, E., Salemme, R., Hayward, V., Farnè, A. (under review) Sensing with tools extends information processing beyond the body.

Short Biography

Luke E. Miller completed his PhD in the Cognitive Science department at the University of California, San Diego. His thesis work focused on how tool use recalibrates internal models of the user's body. He is now a postdoctoral fellow at the Center for Neuroscience Research in Lyon and INSERM U1028 ImpAct Team. His current research aims to characterize the many levels of information processing that underlie the ability to sense aspects of the environment with a tool.

Representations of manipulable objects inherited body model distortions

Valeria Peviani*[1,2], Lucia Melloni[23], Gabriella Bottini[1,4]

[1] Brain and Behavioural Sciences Department – University of Pavia, IT
[2] Neuroscience Department – Max Planck Institute for Empirical Aesthetics, Frankfurt am Main, DE
[3]Department of Neurology, New York University School of Medicine - 240 East 38th St, 20th Floor - New York, NY, 10016, USA
[4]Cognitive Neuropsychology Center – ASST Grande Ospedale Metropolitano Niguarda, Milan, IT

Abstract

Previous evidence suggest that we are not accurate in estimating our body dimensions. The shape of the hand representation, in particular, is characterized by a higher ratio between its horizontal and vertical dimensions [1]. Here, we aimed at investigating whether this peculiar pattern of distortions is specific to the hand or is shared by physical entities which do not belong to the body. To achieve this goal, we studied the metric representations of seven different objects, together with that of the hand's, in six experiments involving 157 healthy participants. We used a line length judgment task in which participants were asked to judge the dimensions of lines compared to those of a specific target (hand or previously observed objects). For each target, we computed the perceived and actual shape and size. We ran repeated-measures analyses to draw comparisons among the representations. We found that the peculiar pattern of distortions is not specific to the hand; instead, it is shared by some of the objects studied. However, some other objects did not exhibit such a distortion. In particular, the representations of the mug and of the computer mouse are similar to the hand representation. The mobile is represented as more distorted than the hand. Surprisingly, the fake hand representation resulted accurate in proportion, therefore strikingly different fReferencesnd representation. Instead, the representations of a cactus and a repellent soap exhibited a pattern of distortions opposite to that of the hand. We discussed the possible effects of familiarity, possibility of interaction with the objects and ownership, in order to explain the results.

References

[1] Longo, M. R., & Haggard, P. (2010). An implicit body representation underlying human position sense. Proceedings of the National Academy of Sciences, 107(26), 11727-11732.

Short Biography

After having achieved a summa con laude Master Degree in Cognitive Psychology in 2015 at the University of Pavia (IT), Valeria Peviani joined the Cognitive Neuropsychology Center of Niguarda Hospital in Milan (IT), for her 12-months training in Clinical Neuropsychology. Later, she has been enrolled on the PhD program in "Psychology, Neuroscience and Data Science" at the University of Pavia under the supervision of Professor Gabriella Bottini.

Her research interests are in the field of body representations. Her purpose is to contribute to the understanding of the neuro-cognitive mechanisms underlying how the body is represented in the brain. In particular, her research is currently focusing on the metric body representations.

Since January 2018 she has started a 16-months visiting period at the Neuroscience Department of the Max-Planck Institute for Empirical Aesthetics, where she is working on body and space perception.

A wearable robotic hand to explore complex bodily illusions

The Vu Huynh[1], Alina Bittner[1], Gianluca Saetta[2]*, Bigna Lenggenhager[3], Philipp Beckerle[4]

[1] Technische Universität Darmstadt, Germany
[2] Department of Neurology, Neuropsychology Unit, University Hospital Zurich, Switzerland
[3] Department of Psychology, Cognitive Neuropsychology, University of Zurich, Switzerland
[4] Institute for Mechatronic Systems in Mechanical Engineering, Technische Universität Darmstadt, Germany.

Abstract

The numbness illusion (Dieguez, Mercier, Newby, & Blanke, 2009) refers to the sensation of numbness when two people put their hands against each other and the participants slowly stroke both index fingers. Similar to the widely studied rubber hand illusion paradigm (Botvinick & Cohen, 1998), the numbness illusion is used to investigate the plasticity of the bodily self and the incorporation of foreign body parts into one own's body schema. However, in contrast to the rubber hand approach, the numbness illusion depends on more complex actions and crucially requires tactile feedback (both from touching one's own and the other person's body part). We therefore developed a wearable robotic device, to account for this complexity. It uses servo and vibration motors to provide motor and tactile feedback and is directly attached to the participant's forearm. This enables the participant to move the robotic arm freely. A preliminary study with a similar, but stationary robotic hand has shown, that the numbness illusion can be partially replicated using a robotic hand: the results show no significant differences in the numbness illusion between the real hand and the robotic hand and the results were comparable to the original numbness illusion (Dieguez et al., 2009). However, while the feeling of agency for the robotic hand was high, the feeling of ownership was rather low. We speculated that the movement restriction of the stationary robotic hand might be the cause for the low ownership results and expect thus the new wearable version of the robotic hand to yield higher results. These results would indicate the embodiment of the robotic hand and might have important implications for future prosthetic research.

References

Botvinick, M., Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. Nature, 391: 756.

Dieguez, S., Mercier, M. R., Newby, N., Blanke, O. (2019). Feeling numbness for someone else's finger. Current Biology, 19(24): R1108-R1109.

Short Biography

Gianluca Saetta is a PhD candidate in Clinical and Cognitive Neuroscience at University Hospital of Zurich. He completed his master's degree in Cognitive Neuroscience and his research internship at University Milano-Bicocca investigating the neurophysiological underpinnings of complex body representation disorders. Combining methods from behavioural neurology, psychology and artificial intelligence, his actual research contribution consists in the characterisation of the multisensory and plastic mechanisms leading to the construction of a unitary and coherent body representation in both healthy participants and in clinical populations (with a particular focus on traumatic amputees with phantom sensations, absent congenital limb and xenomelic individuals).

Bimanual sensorimotor system is more effective than a unimanual system

Hunter R. Schone[1]*, Roni O. Maimon-Mor[1,2], Peter Brugger[3] & Tamar R. Makin[1,2]

[1] Institute of Cognitive Neuroscience, University College London, London, UK
[2] FMRIB Centre, Nuffield Department of Clinical Neuroscience, University of Oxford, Oxford, UK
[3] Department of Neurology, Neuropsychology Unit, University Hospital Zurich, Zurich, Switzerland

Abstract

There's a school of thought suggesting that our sensorimotor body experiences affect the way visual information is interpreted and even processed. However, recent evidence has challenged this idea by demonstrating that individuals born without hands perform similar to typically developed controls on tasks that assess hand perception, representation, and judgements of visual body information (Vannuscorps & Caramazza, 2016). While it has been suggested that the ability to represent and judge visual body information is innate and entirely decoupled from individual motor experience, it's possible passive visual experience of hands could be a sufficient teacher of body perception, at least for basic behaviors and biomechanical constraints. Here, we asked if motor hand experience is recruited to optimise visual decision making of hand laterality. We studied three groups of individuals with similar passive visual hand experience, but different amounts of motor hand experience: congenital one-handers (individuals born without one hand), acquired one-handers (hereafter, amputees) and two-handed controls. We show that congenital one-handers make more judgement errors for hand images of their intact hand than their missing. Additional analysis revealed that congenital one-handers have a bias to judge images as their missing hand. Further, we show that congenital one-handers were slower to respond to hands than amputees and controls. While, amputees, who have persistent representation of their missing (phantom) hand (Makin et al. 2013), responded as fast as controls. Amputees' response time to hands was correlated to their phantom hand's motor control abilities, thus greater motor control of the phantom hand facilitates faster response time to hands. This result suggests that bimanual motor control optimises the cognitive processes involved in judging visual hand information. Finally, we propose a novel computational model that demonstrates that a bimanual sensorimotor system is more effective at solving a hand laterality judgement task than a unimanual system.

References

Makin, T.R., Scholz, J., Filippini, N., Henderson Slater, D., Tracey, I. and Johansen-Berg, H. (2013). Phantom pain is associated with preserved structure and function in the former hand area. Nature Communications, 4: 1570.

Vannuscorps, G. and Caramazza, A. (2016). Typical action perception and interpretation without motor simulation. Proc Natl Acad Sci USA, 113: 86-91.

Short Biography

Hunter R. Schone is a doctoral student at the University College London and the National Institutes of Health. His research highlights the brain plasticity of individuals missing a hand. His current work investigates the cognitive representation of both hands and artificial prosthetic hands to better understand how the brain facilitates prosthesis usage.

Neural correlates of distorted body representations underlying tactile distance perception

Luigi Tamè[1]*, Raffaele Tucciarelli[1], Renata Sadibolova[1], Marty Sereno[1,2,3], Matthew Longo[1]

[1] Department of Psychological Sciences, Birkbeck, University of London, London, UK
[2] University College London, University of London, London, UK
[3] San Diego State University, San Diego, USA

Abstract

The ability to localize touch on the body has been largely used as a tool to investigate how the somatosensory system contributes to body representations. Recent studies found that at perceptual level, tactile configurations at least in the case of the hand are highly distorted (Longo, 2017). Here, we aim to define the neural basis of this phenomenon. In a behavioral experiment, participants estimated the distance between touches delivered on the hand dorsum. Using multidimensional scaling we reconstructed a perceptual map of the skin space. Analysis of spatial distortion showed that the skin space was stretched in the mediolateral hand axis. To determine the neural correlates of these body distortions, we performed a functional magnetic resonance (fMRI) study in which we delivered nine tactile stimuli, organized as a 3 x 3 square grid, on the dorsum of the right hand. Within pre-defined regions of interests, we computed the pairwise Euclidean distances between the neural patterns associated with the tactile stimulations and we compared the neural dissimilarity matrices to the model obtained from the behavioral study. We were able to reconstruct the shape of the skin space in the contralateral primary somatosensory (SI) and motor cortices, with a distorted profile that emerged only in the SI. This suggests that these areas are critical to generate the tactile representations of the dorsum of the hand.

References

Longo, M. R. (2017). Distorted body representations in healthy cognition. Quarterly Journal of Experimental Psychology, 70, 378-388.

Short Biography

*My Research interest concerns the various aspects of sensory perception and sensory-motor interaction. I use and combine psychophysics, neuroimaging (e.g., fMRI, MEG, EEG, TMS) techniques in order to define the behavioural and neural correlates of these phenomena. I am particularly interested in the sense of touch, its interactions with the other senses and the motor system, the way in which touch is represented and elaborated by our brain.

HAPTICS AND NEUROREHAB

Can humans perceive frictional differences just by touching surfaces?

Naqash Afzal[1,4*], Heba Khamis[2,4], Jennifer Sanchez[1], Michael Wiertlewski[3], Stephen J. Redmond[2], Richard Vickery[1,4], and Ingvars Birznieks[1,4]

[1] School of Medical Sciences, UNSW Sydney, Sydney, NSW, Australia
[2] Graduate School of Biomedical Engineering, UNSW Sydney, Sydney, NSW, Australia
[3] National Centre for Scientific Research, Aix-Marseille University, Marseille, France
[4] Neuroscience Research Australia, Randwick, NSW, Australia

Abstract

To hold an object safely, humans adjust grip forces to frictional conditions without exploratory sliding movements; we simply grip and lift. Frictional information must be conveyed by tactile afferents to the motor control system, however, this is not necessarily consciously perceivable. We explored human perception of differences in static friction between surfaces during initial contact, with no sliding movement, both with and without a net tangential force. A two-alternative forced choice protocol was used with seventeen subjects (age 21.7±1.4 years mean ± SD; 7 female). A normal force stimulus was applied to the immobilized finger, and the subject indicated which of the paired stimuli was slipperier (perceptual correlate of friction). Three different friction levels were delivered using an ultrasonic friction modulation device [1]. The ratio of frictions between highest vs. medium, and medium vs. lowest friction levels, was 2.2±0.4 and 1.6±0.2 (mean ± SD), respectively. When no net tangential force was present, subject performance was at chance level (56%±16%, and 47%±13% (mean correct ± SD), with/without friction cues being available on stimulus retraction, respectively). When adding a net tangential force (approach angle 20° to the normal), subject performance remained at chance level (62%±15% and 50%±15% (mean correct ± SD), with/without friction cues being available on stimulus retraction, respectively). This indicates that humans cannot perceive frictional variations of smooth surfaces just by touching them when no exploratory sliding movement is allowed. Localized slips on a smooth surface without displacement of a textured pattern may not provide sufficient perceptual cues for judging frictional differences [2]. Also, subjects did not use cues from friction-dependent fingertip deformations [3] which elicit responses in tactile afferents. Frictional information on contact is available for motor control, but may not contribute to a perceptual counterpart.

References

[1] Wiertlewski, M., Friesen, R.F., and Colgate, J.E. (2016). Partial squeeze film levitation modulates fingertip friction. Proceedings of the National Academy of Sciences, 113: 9210-9215.

[2] Srinivasan, M.A., Whitehouse, J., and LaMotte, R.H. (1990). Tactile detection of slip: surface microgeometry and peripheral neural codes. J. Neurophysiol., 63: 1323-1332.

[3] Delhaye, B., Barrea, A., Edin, B.B., Lefevre, P., and Thonnard, J.-L. (2016). Surface strain measurements of fingertip skin under shearing. J. Royal Soc. Interface, 13: 20150874.

Short Biography

Naqash Afzal is a Scientia PhD Scholar in the Tactile research lab at the School of Medical Sciences, UNSW Sydney, Australia. He joined an inter-disciplinary team focusing on the encoding of information in the tactile sensory system and sensorimotor control of the hand, bringing with him his experience in tribology and haptics.

Light-touch based Virtual Cane for assistance during walking

Sindhu Reddy Alluri[1]*, Devin Burns[2], Yun Seong Song[1]

[1] Mechanical and Aerospace Engineering, Missouri University of Science and Technology
[2] Psychological Science, Missouri University of Science and Technology

Abstract

Can additional information about one's body kinematics provided through hands improve human balance? Instead of using physical assistance, it was shown by Jeka [1] that Light-Touch (LT) through hands helps improve balance in a wide range of populations, both healthy and impaired. The force is too small to provide any meaningful mechanical assistance – rather, it is suggested that the additional sensory information through hands helps the body improve balance. Indeed, Shima [2] showed that the information about one's hand location provided through vibrations could improve standing balance.

To investigate the potential for improving walking balance through biofeedback through hands, we developed a Virtual Cane (VC) for balance assistance during walking. The current VC prototype is in the form of an instrumented glove, including bend sensors, vibration actuators, and infra-red (IR) distance sensors. The VC mimics the physical cane's function of providing information about one's body in space. Currently, pilot experiments on 3~5 healthy young adults are planned in June-July 2018, where the evidence of improved walking balance with VC will be collected and analyzed in terms of medio-lateral acceleration of the trunk.

This work furthers the concept of biofeedback from using virtual devices for walking balance assistance - using virtual LT through hands. Specifically, this work investigates a novel case where information that otherwise cannot be provided by any of the sensory organs (i.e., accurate distance from one's hand to an external object), improves human walking balance.

References

[1] Jeka JJ, Lackner JR. (1994). Fingertip contact influences human postural control. Exp. Brain Res.;100(3):495-502.

[2] Shima K, Kohno R. (2013). Virtual Light Touch Contact: A Novel Concept for Mitigation of Body Sway.7th International Symposium on Medical Information and Communication Technology (ISMICT): Article no. 6521710, Page no. 108-111.

Short Biography

Sindhu Reddy Alluri is a graduate research assistant at Missouri S&T pursuing Master of Science in Manufacturing Engineering since August 2017. She also worked as a graduate teaching assistant for Mechanical Dynamics at Missouri S&T. Prior to this, she worked as a Maintenance Engineer in Innovation & Digitization department in Mahindra & Mahindra, India from 2016-2017. She graduated with Bachelor of Technology degree in Mechanical Engineering (Mechatronics) in 2016, from Jawaharlal Nehru Technological University of Hyderabad, India.

Alpha neurofeedback training regulates interindividual variability in tactile learning

Marion Brickwedde[1,2]*, Hubert R. Dinse[1,2]

[1] Institute for Neuroinformatics - Neural Plasticity Lab, Ruhr-Universität Bochum, Bochum, Germany
[2] Department of Neurology, BG-University Clinic Bergmannsheil, RUB, Bochum, Germany

Abstract

Oscillatory alpha power is believed to occupy an inhibitory function which gates neuronal resources. To obtain information about processes controlling learning variability, we have previously shown that baseline power of somatosensory alpha recorded before tactile learning predicted 36 % of the learning variance (Freyer et al. 2013, J Neurosci). Here we took advantage of these findings by aiming at purposefully altering somatosensory alpha power to systematically manipulate subsequent learning success in human participants.

A total of 74 participants were randomly assigned to three groups. The first group (alpha up) trained to increase, while the second group (alpha down) trained to decrease somatosensory alpha power using a neurofeedback system. The control group performed no neurofeedback training. After neurofeedback training, we induced perceptual learning with high frequency LTP-like repetitive sensory stimulation (RSS) applied to the right fingertip, which has been shown to reliably induce tactile learning, correlating with plastic changes in the SI (Dinse et al., 2003 Science). Before and after RSS, we assessed the tactile spatial discrimination ability as marker of plastic changes.

The alpha up group showed significantly higher tactile learning gains than controls. In contrast, in the alpha down group tactile learning was suppressed. In both neurofeedback training groups, alpha power levels could explain up to 59% of the perceptual learning variability.

Our results suggest that an optimal state for perceptual learning can be facilitated with short-term neurofeedback training.

References

Freyer, F., Becker, R., Dinse, H. R. & Ritter, P. (2013). State-dependent perceptual learning. J Neurosci 33,2900-2907 (2013).

Dinse, H. R., Ragert, P., Pleger, B., Schwenkreis, P. & Tegenthoff, M. (2003). Pharmacological modulation of perceptual learning and associated cortical reorganization. Science 301, 91-94.

Short Biography

Marion Brickwedde studied psychology at the University of Trier and aquired her Master under Supervision of PD Dr. Hubert Dinse (Ruhr-University Bochum). Currently she is graduating in the International Graduate School of Neuroscience at the Ruhr-University of Bochum.

Two Frequencies, One Pitch: Exploring Pitch Perception When Scanning Multi-frequency Textures

Rebecca F. Friesen[1]*, Roberta L. Klatzky[2], Michael A. Peshkin[1], J. Edward Colgate[1]

[1] Northwestern University
[2] Carnegie Mellon University

Abstract

To what extent does our somatosensory system retain the frequency-rich content of vibrations produced during fingertip texture exploration? Tactile vibrations while scanning play an important role in our ability to discriminate the myriad textured objects we encounter every day. The way that we process these vibratory signals is not well understood and has been subject to much exploration over the past several decades. To explore how people might simplify their perception of rich frequency information, our recent work explores whether subjects can identify a single frequency, or pitch, when feeling textures composed of two spatial frequency components. We created textures with customized frequency content using a variable friction display, and probed pitch perception by having subjects adjust a single spatial frequency to perceptually match a texture with two frequency components. Subjects generally identified a pitch between the two frequencies of the given texture and weighted by the amplitude ratio of these two components. In contrast to our acoustic perception of pitch for two distinct tones, these results suggest that we can integrate two tactile vibrations into the perception of a single pitch.

References

Friesen, R.F., Klatzky, R.L., Peshkin, M.A. and Colgate, J.E. (2018). Single Pitch Perception of Multi-frequency Textures. Haptics Symposium, 2018 IEEE, 290–295. [link]

Short Biography

Becca is a 5th year PhD candidate in Mechanical Engineering at Northwestern University. Her research in surface haptics seeks to understand the most perceptually relevant characteristics of texture, with an emphasis on our perception of vibrations induced by the scanning of micro scale textural features. She hopes to use this work to guide the design and modification of distinguishable textures on variable friction display screens. Prior to graduate school, she worked as a technician in a Northwestern neural engineering lab investigating the cortical underpinnings of proprioception and motor control of the hand.

Beneficial effects of action video game playing on tactile learning

Marie C. Krüger*[1,2], Hubert R. Dinse[1,3]

[1] Institute for Neural Computation- Neural Plasticity Lab, Ruhr-University Bochum, Germany
[2] International Graduate School of Neuroscience, Ruhr-University Bochum, Germany
[3] Department of Neurology, BG-University Clinic Bergmannsheil, RUB, Bochum, Germany

Abstract

Playing an *action video game* (AVG) has positive influences on a wide range of cognitive functions and perceptual skills, suggesting generalized learning (Green and Bavelier, 2012, Curr Biol). Here we hypothesize, that players of AVGs show enhanced performance in a standard perceptual learning paradigm. To this aim, we implemented *repetitive sensory stimulation* (RSS) of the fingertip, which has been shown to reliably improve tactile acuity in parallel with plastic reorganizational changes in the somatosensory cortex (Dinse et al., 2003, Science). Participants were recruited as *players (*defined as 10-20 hours of playing AVGs at a PC per week) or *non-player*s (non AVG-playing; max 5 hours of playing nonAVGs per week). During the 20 minutes of application of RSS, each subject participated in either a playing (Unreal Tournament – a classical AVG, Solitaire or Sims), or non-playing condition with reading or listening to music, serving as a control for the playing condition.

First, our data confirm the repeatedly shown improvement of tactile acuity after RSS. However, non-players revealed a distinct decline of the tactile performance in the AVG condition compared to controls. In contrast players maintained usual learning capabilities, but showed no higher perceptual learning capacities compared to non-players. This indicates beneficial effects for players to show normal learning even under conditions that impose a high load on mental resources related to attention, decision, and execution processes.

References

Green, C. & Bavelier, D. Learning, attentional control, and action video games. Curr. Biol. 22, R197–R206 (2012).

Dinse H., Ragert P., Pleger B., Schwenkreis P., Tegenthoff M. Pharmacological modulation of perceptual learning and associated cortical reorganization. Science 301: 91-94 (2003)

Short Biography

Marie C. Krüger completed her studies in neurobiology at the Ruhr- University Bochum (Germany) with her master thesis “Influence of action video games on learning processes in humans”. Since 2014 she is a member of the International Graduate School of Neuroscience (IGSN -Ruhr-University Bochum, Germany). Under the Supervision of PD Dr. Hubert R. Dinse at the Neural Plasticity Lab she is working on her PhD project “Influences of action video games on perceptual learning”.

Somatosensory and motor reorganization after stroke: Evidence from fMRI in humans

Jared Medina*, Yuqi Liu

[1] Department of Psychological and Brain Sciences, University of Delaware

Abstract

Cortical plasticity subsequent to brain damage has been studied extensively in non-human primates, providing evidence for cortical reorganization. However, relatively little research has been done in humans examining how somatosensory representations change after brain damage. We used fMRI and DTI to examine somatosensory and motor plasticity in a series of brain-damaged individuals. To assess basic performance, all participants received a battery of somatosensory (tactile detection and localization) and motor (grip strength, finger tapping) tests outside of the scanner. Next, participants were placed in the scanner and presented with tactile stimulation to each hand (either via manual brush stroke or piezoceramic tactile stimulators attached to the fingertips), followed by a separate motor task for each hand (timed opening and closing of the hand). We then used single-subject analyses to compare activation for touch/movement versus rest. One individual had a unique lesion with extensive damage to left primary somatosensory cortex (S1) and posterior parietal cortex, with left motor cortex (M1) and subcortical structures primarily intact. In behavioral testing, he was impaired at tactile localization and had diminished tactile detection; but could still detect moderate tactile stimuli – suggesting cortical reorganization. As expected, he demonstrated right S1 activation when stimulating his ipsilesional left hand. However, stimulation of his contralesional right hand resulted in activation in left M1, consistent with animal models that show reorganization into motor cortex after S1 damage (Harrison et al., 2013). During movement of the contralesional right hand, we found decreased activity in left M1, inactivation of right anterior cerebellum, and increased activation in bilateral putamen relative to controls. We discuss how this individual and other cases provide evidence for different patterns of sensorimotor reorganization after brain damage in humans.

References

Harrison, T.C., Silasi, G., Boyd, J.D. & Murphy, T.H. (2013). Displacement of sensory maps and disorganization of motor cortex after targeted stroke in mice. Stroke, 44, 2300-2306.

Short Biography

Jared Medina is an associate professor in the Department of Psychological and Brain Sciences at the University of Delaware. His research focuses on how the brain represents the body, including topics such as tactile detection and localization, cortical reorganization and multisensory integration. To address these topics, he uses cognitive neuropsychology, TMS, fMRI, and psychophysics.

Tactile learning at the hand transfers to the face but not to the forearm: evidence for a special hand-face relationship

Dollyane Muret[1,2]*, Hubert R. Dinse[1,2]

[1] Neural Plasticity Laboratory, Ruhr-University, 44801 Bochum, Germany;
[2] Clinic of Neurology, BG University Hospital Bergmannsheil, 44789 Bochum, Germany;

Abstract

It is not well-understood how cortical plasticity translates into perceptual abilities and what are its limits. In the primary somatosensory cortex (SI), large-scale cortical and perceptual changes have been demonstrated following input deprivation. Recently, we found that the cortical and perceptual changes induced by repetitive somatosensory stimulation (RSS) at a finger (see Beste and Dinse, 2013 for a review) transfer both to the face (Muret et al., 2014, 2016). However, whether such cross-border changes are specific to the face remains elusive. In a first experiment, we investigated whether RSS-induced acuity changes at the finger can also transfer to the forearm, which is the body part represented on the other side of the hand representation. Our results confirmed the transfer of tactile learning from the stimulated finger to the lip, but no significant changes were observed at the forearm. A second experiment revealed that the same regions on the forearm exhibited improved tactile acuity when RSS was applied there, excluding the possibility of low plastic ability at the arm representation. This provides also the first evidence that RSS can provide perceptual benefits on body parts other than the hand. While a delayed effect on the forearm cannot be excluded, these results suggest that RSS-induced tactile learning transfers preferentially from the hand to the face rather than to the forearm. This preference could arise from a stronger functional connectivity between the cortical hand and face representations, reflecting a fundamental coupling between these body parts.

References

Beste, C., and Dinse, H.R. (2013). Learning without training. Curr. Biol. 23, R489-99.

Muret, D., Dinse, H.R., Macchione, S., Urquizar, C., Farnè, A., and Reilly, K.T. (2014). Touch improvement at the hand transfers to the face. Curr. Biol. 24, R736-7.

Muret, D., Daligault, S., Dinse, H.R., Delpuech, C., Mattout, J., Reilly, K.T., and Farnè, A. (2016). Neuromagnetic correlates of adaptive plasticity across the hand-face border in human primary somatosensory cortex. J. Neurophysiol. 115, 2095–2104.

Short Biography

During my PhD I investigated the limits of cortical somatosensory plasticity and of its functional consequences, in particular across body parts. This work led to a first paper in Current Biology (Muret et al, 2014) showing that RSS on a finger improves tactile acuity not only at this finger but also at the face. Using MEG, we then found that this perceptual transfer is associated with plasticity in the hand and face representations within SI (Muret et al, 2016). The present work was done in the continuity of my PhD, during a post-doc done under the supervision of Dr. Dinse.

Investigating abnormal tactile function in autism using psychophysics, edited MRS of GABA, and TMS

Nicolaas Puts[1,2]*, Stewart Mostofsky[3], Mark Tommerdahl[4], Pablo Celnik, and Richard Edden[1,2]

[1] Russell H. Morgan Department of Radiology and Radiological Science, The Johns Hopkins University School of Medicine, Baltimore, USA
[2] F.M. Kirby Research Center for Functional Brain Imaging, Kennedy Krieger Institute, Baltimore, USA,
[3] Center for Neurodevelopmental and Imaging Research Kennedy Krieger Institute, Baltimore, USA,
[4] Department of Biomedical Engineering, University of North Carolina at Chapel Hill, Chapel Hill, USA

Abstract

Autism Spectrum Disorder (ASD) is characterized by abnormal communication and social function. However, sensory abnormalities, especially tactile, are common (95%). Given the importance of touch in early life, abnormal tactile processing may give rise to, or exacerbate, core symptoms of ASD. However, touch in ASD is predominantly assessed using subjective reporting (questionnaires) and the underlying neurophysiology is poorly understood. Several lines of evidence suggest that GABA, the main inhibitory neurotransmitter, is altered in ASD. GABA also plays an important role in encoding tactile information. We hypothesize that altered GABA is linked to abnormal touch in ASD. We developed a battery of psychophysical tasks to objectively measures tactile function in pediatric cohorts, linked to GABA[1]. We are able to measure GABA levels *in vivo* and non-invasively using edited Magnetic Resonance Spectroscopy (MRS)[2]. Finally, GABA-receptor function can be assessed using paired-pulse Transcranial Magnetic Stimulation (TMS). In 35 children with ASD and 35 control children (TDC) between 8-12 years we measured tactile detection and amplitude discrimination using staircase tracking, with a CM4 vibrotactile stimulator (Cortical Metrics). GABA levels were measured at 3T in a voxel over the sensorimotor cortex (SM1; $(3cm)^3$) and occipital cortex (OCC; $(3cm)^3$, TE/TR 68/2000 ms, 320 averages, MEGA-PRESS). Results show that reduced SM1 GABA (but not OCC) in ASD is correlated with worse tactile performance. Pilot TMS data suggest that $GABA_A$, but not $GABA_B$, may be impaired in ASD. This multi-modal approach allows for an investigation of presynaptic (GABA levels) and post-synaptic (TMS) measures of inhibition that relate to behavioral and clinical outcomes (tactile thresholds) in ASD. I will also discuss data in ADHD and Tourette where GABA and touch are impaired. These findings have important implications for our understanding and potential GABA-directed treatment in disorders where GABA plays an important role (such as ASD, ADHD, Stroke).

References

[1] Puts NA, Edden RA, Wodka EL, Mostofsky SH, Tommerdahl M. A vibrotactile behavioral battery for investigating somatosensory processing in children and adults. Journal of Neuroscience Methods [Internet] 2013;218:39–47. doi: 10.1016/j.jneumeth.2013.04.012.

[2] Puts NAJ, Edden RAE. In vivo magnetic resonance spectroscopy of GABA: A methodological review. Progress in Nuclear Magnetic Resonance Spectroscopy [Internet] 2012;60:29–41. doi: 10.1016/j.pnmrs.2011.06.001.

Short Biography

Dr. Nicolaas Puts is Assistant Professor of Radiology at the Johns Hopkins University School of Medicine. His research focus is on studying the role of inhibition in somatosensory impairments in autism (as well as ADHD, Tourette, concussion and recently stroke). He uses tactile psychophysics to study specific aspects of low-level tactile functions (thresholds), and MRS to measure GABA levels in vivo. He has recently started using TMS to study GABA receptor function. He also contributes to the development of new MRS techniques and the Gannet GABA MRS analysis package.

Towards reducing fall risk via haptic communication on a robotic walker

Ramón E. Sánchez Cruz[1]*, Rebecca P. Khurshid[1]

[1] Boston University, Boston, MA, 02215

Abstract

As the life expectancy increases, the population of older adults is projected to rapidly increase. However, this means that age-related health issues, such as injuries following a fall, are also expected to increase. Our long-term research goal is to increase the functionality of common walking aides, and reduce the risk of a fall through instrumentation, informative feedback, and physical action. Although walking aids do exist, the high number of falls that occur with these devices motivates the need for their improvement[1]. Our immediate objective is to develop a system that uses low-cost sensors to assess the usage of the walker, and intuitive haptic, auditory, and visual feedback to provide positive feedback when the use is correct, and guidance when incorrect. Visual feedback is appropriate for some feedback modalities, but domain area experts believe that it will actually increase the risk of a fall by distracting the user. Auditory feedback may be intuitive and easily interpretable for many users, but it may also make the assistive technology more intrusive. Therefore, we choose to focus on ways that haptic feedback can increase correct usage of assistive devices. We intend to evaluate both the utility of haptic feedback from actuators embedded in the walker's handles and haptic feedback from wearable feedback sources. We note that the majority of haptic feedback devices are designed and validated by younger adults with normal sensory motor systems. Because it is known that tactile sensitivity decreases with age[2], this project will require us to re-evaluate several modalities of haptic feedback, such as vibrotactile, skin stretch, and contact with populations of older adults. Based on the findings of these validation, we will likely need to iterate on the design of many haptic devices described in the literature to better enable haptic communication with our target population.

References

[1] Stevens, J. A., Thomas, K., Teh, L., & Greenspan, A. I. (2009). Unintentional fall injuries associated with walkers and canes in older adults treated in US emergency departments. *Journal of the American Geriatrics Society*, *57*(8), 1464-1469.

[2] Wickremaratchi, M. M., and J. G. Llewelyn. (2006). "Effects of ageing on touch." *Postgraduate medical journal* 82.967: 301-304.

Short Biography

From a young age, my desire to help those with medical needs became a driving force in directing my career aspirations. I earned my undergraduate degree in mechanical engineering at the University of Puerto Rico at Mayaguez, where I enjoyed helping others through mechanical approaches. As a PhD student in the CAIR Lab, I am working to create a robotic system for fall prevention on the elderly. My goal is to create a system that analyzes the person's gait to detect any anomalies that indicate the risk of a fall, and prevent it from happening in real time.

Use of imperceptible wrist vibration to modulate sensorimotor cortical activity

Na Jin Seo[1]*, Kishor Lakshminarayanan[2], Abigail Lauer[3], Viswanathan Ramakrishnan[3], Brian D. Schmit[4], Colleen A. Hanlon[5], Mark S. George[5], Leonardo Bonilha[6], Ryan Downey[1], Will DeVries[5], Tibor Nagy[7]

[1] Department of Health Professions, Medical University of South Carolina, SC, USA
[2] Department of Industrial Engineering, University of Wisconsin-Milwaukee, WI, USA
[3] Department of Public Health Sciences, Medical University of South Carolina, SC, USA
[4] Department of Biomedical Engineering, Marquette University, WI, USA
[5] Department of Psychiatry & Behavioral Sciences, Medical University of South Carolina, SC
[6] Department of Neurology, Medical University of South Carolina, SC, USA
[7] Department of Chemistry, Appalachian State University, NC, USA

Abstract

Background: Peripheral sensory stimulation has been used as a method to stimulate the motor cortex, with applications in neuro-rehabilitation. To improve delivery modality and usability, a new stimulation method has been developed in which imperceptible random-frequency vibration is applied to the wrist concurrently during hand activity.
Objective: The objective of this study was to investigate effects of this new sensory stimulation on the sensorimotor cortex.
Methods: Health adults were studied. In a transcranial magnetic stimulation (TMS) study, resting motor threshold, short-interval cortical inhibition, and cortical facilitation for a hand muscle were compared between vibration on vs. off while subjects were at rest. In an electroencephalogram (EEG) study, alpha and beta power during rest and hand grip were compared between vibration on vs. off.
Results: Vibration decreased EEG alpha and beta power during grip and rest and also decreased TMS short-interval cortical inhibition (i.e., disinhibition) compared with no vibration.
Conclusion: Subthreshold random-frequency wrist vibration affected cortical activity and release of cortical inhibition. Such effects may have implications in rehabilitation.

Short Biography

Na Jin Seo, PhD is an Associate Professor in Division of Occupational Therapy at Medical University of South Carolina. Her research focuses on hand rehabilitation post stroke and is using sensory stimulation to impact motor function in stroke survivors.

Tactile Masking by Electrovibration

Yasemin Vardar[1,2]*, Cagatay Basdogan[2], Burak Güçlü[3]

[1] Max Planck Institute for Intelligent Systems, Haptic Intelligence Department
[2] Koç University, Department of Mechanical Engineering
[3] Boğaziçi University, Institute of Biomedical Engineering

Abstract

Future touch screen applications will include multiple tactile stimuli displayed simultaneously or consecutively to single finger or multiple fingers. These applications should be designed by considering human tactile masking mechanism since it is known that presenting one stimulus may interfere with the perception of the other. In this study, we investigate the effect of masking on the tactile perception of electrovibration displayed on touch screens. Through conducting psychophysical experiments with nine participants, we measured the masked thresholds of sinusoidal electrovibration bursts (125 Hz) under two masking conditions: simultaneous and pedestal. The masking stimuli were noise bursts, applied at five different sensation levels varying from 2 to 22 dB SL, also presented by electrovibration. For each participant, the detection thresholds were elevated as linear functions of masking levels for both masking types. We observed that the masking effectiveness was larger with pedestal masking than simultaneous masking. Moreover, in order to investigate the effect of tactile masking on our haptic perception of edge sharpness, we compared the perceived sharpness of edges separating two textured regions displayed with and without various masking stimuli. Our results suggest that sharpness perception depends on the local contrast between background and foreground stimuli, which varies as a function of masking amplitude and activation levels of frequency-dependent psychophysical channels.

References

Vardar, Y., Basdogan, C., and Güçlü, B. (2017). Effect of waveform on tactile perception by electrovibration displayed on touch screens. IEEE Transactions on Haptics, 10(4): 488-499.

Short Biography

Yasemin Vardar is currently a post-doctoral researcher in the Haptic Intelligence department in Max Planck Institute for Intelligent Systems. She received her Ph.D. degree in mechanical engineering from Koç University, Istanbul in 2018. Before starting her PhD study, she conducted research on control of high precision systems in ASML, Philips, and TNO Eindhoven. She received her MSc degree in systems and control from the Eindhoven University of Technology in 2012, and B.Sc. degree in mechatronics engineering from Sabanci University, Istanbul in 2010. Her research interests are haptics science and technology.

Do we explore with the optimal fingers? Spontaneous exploration and performance with different fingers in softness discrimination

Aaron C. Zoeller[1]*, Knut Drewing[1]

[1] Justus-Liebig-University Giessen, Germany

Abstract
In studies of haptic softness perception, typically only a limited range of different exploration behaviors is used. Most frequently, participants are instructed to explore soft objects by indenting them with their index finger. In contrast, performance with the other fingers or simultaneous indentation with more than one finger has rarely been investigated. Yet, Katz (1989/1925) described that in spontaneous exploration, people tend to use several fingers (often middle and index finger). We wondered if fingers differ in their ability to discriminate softness, and if so, which fingers are spontaneously used. First we studied exploration phases and fingers used in spontaneous exploration. Eighty-seven participants discriminated the softness of two similar objects while we filmed the finger movements. Results indicate that people perform multiple phases during an exploration, in which they successively use different fingers and finger combinations to explore. Participants most frequently used three different fingers during the exploration, preferring combinations of index, middle and ring finger, avoiding the use of the small finger. Second we compared discrimination thresholds between conditions, with participants using any of the four fingers of the dominant hand. Participants compared the softness of rubber stimuli in a 2AFC discrimination task, using constant forces and executing only one indentation per stimulus in each trial. Performance with the small finger was worse than performance with any of the other three fingers (index, middle, ring); whereas the other fingers did not differ in their ability to discriminate softness. We conclude that using only a single finger to explore the softness of objects does not represent natural behavior completely. Combinations of index, middle, and ring finger seem to be more natural for haptic exploration. This behavior seems to be well chosen, as indicated by improved performance with the spontaneously used fingers compared to the rarely used small finger.

References
Katz, D. (1989/1925). The world of touch (L. E. Krueger, Ed.). Hillsdale, NJ, US: Lawrence Erlbaum Associates, Inc. [Originally published 1925 in Zeitschrift Für Psychologie].

Short Biography
Aaron C. Zoeller studied at the Justus-Liebig-University in Giessen and received a Master's degree in psychology in 2016. Currently, he works as a PhD student in experimental and perceptual psychology in the Department of General Psychology at Giessen University. The main focus of his research is on active haptic touch, specifically, the multisensory integration of prior visual information in a natural multi-segmented haptic exploration process.

Intuitive Haptic Telemanipulator for Laser Osteotomy with a Robotic Endoscope

Esther I. Zoller[1]*, Patrick Salz[1], Azhar Zam[1], Philippe C. Cattin[1], Georg Rauter[1]

[1] Department of Biomedical Engineering, University of Basel, Switzerland

Abstract

Performing minimally invasive robot-assisted laser osteotomy by teleoperation poses several challenges. Not only does the surgeon need to reach a precise position (3 degrees of freedom (DoF)) with the end-effector inside the patient's body, the end-effector also needs to be oriented precisely for the laser beam to cut the bone at the desired angle (another 2 DoF). Additionally, the manipulability of the endoscope's end-effector is constrained by the physical limitations of both the master and slave devices, the anatomy of the surgeon's hand and wrist, and the anatomical environment at the surgical site [1].

In the herein proposed work, different prototypes of a master device handle are developed and evaluated in order to allow intuitive control of a robotic endoscope end-effector for laser osteotomy. Based on eight basic geometric forms and two fundamental grasping types (using the whole hand vs. using the fingertips only), a total of 43 different prototypes were developed. These prototypes were rated subjectively with respect to their grasping comfort, ergonomics, association with everyday objects, and their ease of handling while being mounted on a lamda.6 master device (Force Dimension, Nyon, Switzerland). According to this first evaluation, the number of pursued prototypes was reduced and their design refined. For the resulting 10 prototypes, we are currently evaluating the rotational workspace that can be reached by a human user without changing the grasp of the handle on the lambda.6 device. Additionally, the different handle prototypes are evaluated in a path-following and positioning task mimicking the approach of the endoscope end-effector to its cutting location in a virtual human knee. We strongly believe that the data gained from these experiments will help us to understand better how a master device handle should be designed for a given task to allow the surgeon to intuitively manipulate a robotic endoscope.

References

[1] Zareinia, K., Maddahi, Y., Ng, C., Sepehri, N., Sutherland, G.R. (2015). Performance evaluation of haptic hand-controllers in a robot-assisted surgical system. The International Journal of Medical Robotics and Computer Assisted Surgery, 11: 486–501.

Short Biography

Esther Zoller studied Human Movement Sciences at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland. During her master studies she got increasingly interested in the field of human robot interaction. After completing an internship at the Sensory-Motor Systems (SMS) Lab at ETH Zurich where she worked on error detection and correction of robotic assistance of an upper extremity exoskeleton, she joined the Bio-Inspired RObots for MEDicine Lab (BIROMED-Lab) at the University of Basel in August 2016 where she's currently working as a PhD student focusing on the development of an intuitive haptic teleoperation system for a robotic endoscope.

NEUROPROSTHETICS AND MODELLING

Deep Learning spatio-temporal representations of natural hand movements

Chaiyawan Auepanwiriyakul[1] and Aldo Faisal[1,2,3]

Brain & Behavior Lab: [1] Dept. of Computing,
[2] Dept. of Bioengineering,
[3] Data Science Institute, Imperial College London, London, UK,

Abstract

Natural hand movements controlled by our brain are very variable and complex. Our aim is to identify in a data-driven manner an underlying simplicity that may reflect on the neural mechanisms. Deep Learning techniques have been shown to successfully model representations of auditory and visual cortical areas when presented with the same stimuli [1]. However purely perceptual representations may be significantly different from proprioceptive representations that are as closely linked to ongoing actions and tasks. We therefore developed a novel deep convolutional autoencoder architecture that we have termed the "Angel Encoder". An Angel Encoder is a specialised version of a Nonlinear AutoRegressive Convolutional Autoencoder with Exogenous Inputs that can capture locally hidden spatio-temporal correlated representations from natural hand movements conditioned on the ongoing task and activity. To this an we use intercalated convolutional architecture which operates across spatial and temporal domains simultaneously. We hypothesised that, with training learning on natural hand movements of 10 human subjects from daily life recordings, our Angel Encoder would be able to learn meaningful representations from this natural hand movement data that we collected using left and 22 Degrees of Freedom CyberGloves living in a studio flat environment. We train and evaluate our Angel Encoder on our in-house natural hand movement data recorded [2,3]. We then visualise, at the bottleneck of our neural network, the spatio-temporal neural representations of natural hand movements. Our result shows that the Angel Encoder is capable of uncovering meaningful internal representations of hand movements such as mixed hand activities (e.g. rhythmic tapping) as well as specific simple grasps (e.g. prismatic grips) as well as compound actions. These findings enable us to further our understanding of how the brain perceives hand movement by e.g. correlating these with neural activity [4] as much as suggesting novel ways for controlling robotic and prosthetic hands.

References

[1] Yamins, D. L., & DiCarlo, J. J. (2016). Using goal-driven deep learning models to understand sensory cortex. Nature neuroscience, 19(3), 356.

[2] Belic, J. and Faisal, A. A. (2015). Decoding of human hand actions to handle missing limbs in neuroprosthetics. Frontiers in Computational Neuroscience, 9: 27.

[3] Thomik, A. A., Fenske, S., & Faisal, A. A. (2015, April). Towards sparse coding of natural movements for neuroprosthetics and brain-machine interfaces. IEEE Neural Engioneerin 7:938-941. IEEE.

[4] Gallego, J. A., Perich, M. G., Miller, L. E., and Solla, S. A. (2017). Neural manifolds for the control of movement. Neuron, 94(5):978–984.

Short Biography

Chaiyawan Auepanwiriyakul received BEng in Electrical Engineering from Chulalongkorn University, Thailand and MSc in Human Biological Robotics from Imperial College London, UK, respectively. He is currently a PhD student at Brain & Behaviour Lab, Imperial College London. His PhD research involves studying the neural representations of human body dynamics and their links to human behaviours by using deep learning techniques. He is interested in applying machine learning techniques such as neural networks to human ethomics data as well as how human ethomics data interact with neural networks.

Sensory and motor parameter estimation for elbow myoelectric control with vibrotactile feedback

Matthieu Guémann[1]*, Sandra Bouvier[2], Christophe Halgand[1], Léo Borrini[3], Florent Paclet[1], Éric Lapeyre[3], Damien Ricard[4], Daniel Cattaert[1], Aymar de Rugy[1]

[1] INCIA CNRS UMR 5287, Bordeaux, France
[2] Université Paris Descartes
[3] Department of Rehabilitation at the Army Instruction Hospital, Clamart, France
[4] Department of Neurology at the Army Instruction Hospital, Clamart, France

Abstract

Despite technological advances in motorization of upper limb prosthesis, myoelectric control requires a long learning process leading to a high dropout rate among amputees. The absence of sensory feedback is very likely to impinge the appropriation of the prosthesis. Here, we explored a sensory substitution alternative with various configurations and settings for vibrotactile feedback as a preliminary step toward their future integration.

Six vibrators were placed either on a line between the acromion and the lateral epicondyle or circumferentially around the arm. Space intervals between vibrators were either absolute (2cm) or proportional to the length or the circumference of the arm. Four dispositions were tested: longitudinal proportional (LP), longitudinal absolute (LA), circular proportional (CP) and circular absolute (CA). Combinations of stimulation used involved three durations (60; 100 140ms) and three intensities (62.5; 100; 167mA). Spatial discrimination test involved subjects to estimate location of the vibration, and perceived intensity was assessed by having subjects indicating the strength of the stimulation they experienced between 0 (no feeling) to 3 (strong).

The circular proportional (CP) disposition elicited better discrimination results than the 3 other dispositions ($p<0.0001$). Duration, intensity and disposition were all found to influence the success rate scores. Stimulations with small duration (60ms) were perceived as being produced with a lower level of intensity. Longer or stronger stimulations were perceived stronger.

Our results indicated that a circular proportional disposition of the vibrator around the arm is a well-suited configuration for sensory substitution. Moreover, they provided valuable information on stimulation parameters as time and intensity for vibrators. Our next step will be to combine sensory feedback given by vibrator around the arm (CP) to the myoelectric control of an avatar, on healthy subjects and amputees. This sensory substitution has great potential to improve prosthesis control, acceptance, and might also attenuate phantom limb pain.

References

1. Antfolk C, D'Alonzo M, Rosén B, Lundborg G, Sebelius F, Cipriani C. Sensory feedback in upper limb prosthetics. Expert Rev Med Devices. janv 2013;10(1):45‑54.
2. Markovic M, Schweisfurth MA, Engels LF, Bentz T, Wüstefeld D, Farina D, Dosen S. The clinical relevance of advanced artificial feedback in the control of a multi-functional myoelectric prosthesis. Journal of NeuroEngineering and Rehabilitation. dec 2018;15(1):28.

Short Biography

Matthieu is a Physiotherapist. After working with patients and pushed by his curiosity he wanted to understand the mechanisms underlying the techniques he used. He competed a Master in Rehabilitation with an internship in Montréal, Canada working on movement illusion induced by vibrations on stroke patients. Interested by new technologies associated to the rehabilitation field, and sensible to the unknown condition of the upper limb amputated population, Matthieu came back in France and pursue a PhD in this field exploring solutions to create feedback for prosthetic users. Matthieu has a strong interest in phantom limb pain and patient's living conditions.

Statistical Modelling of Fingertip Deformations and Contact Forces during Tactile Interaction

David Gueorguiev*[1], Dimitrios Tzionas,[1] Claudio Pacchierotti[2], Michael J. Black[1] and Katherine J. Kuchenbecker[1]

[1] Max Planck Institute for Intelligent Systems, 70569 Stuttgart/ 72076 Tübingen, Germany.
[2] CNRS, Univ Rennes, Inria, Irisa, 35000 Rennes, France.

Abstract

Little is known about the shape and properties of the human finger during haptic interaction, even though these are essential parameters for controlling wearable finger devices and deliver realistic tactile feedback. This study explores a framework for four-dimensional scanning (3D over time) and modelling of finger-surface interactions, aiming to capture the motion and deformations of the entire finger with high resolution while simultaneously recording the interfacial forces at the contact. Preliminary results show that when the fingertip is actively pressing a rigid surface, it undergoes lateral expansion and proximal/distal bending, deformations that cannot be captured by imaging of the contact area alone. Therefore, we are currently capturing a dataset that will enable us to create a statistical model of the finger's deformations and predict the contact forces induced by tactile interaction with objects. This technique could improve current methods for tactile rendering in wearable haptic devices, which rely on general physical modelling of the skin's compliance [1], by developing an accurate model of the variations in finger properties across the human population. The availability of such a model will also enable a more realistic simulation of virtual finger behaviour in virtual reality (VR) environments, as well as the ability to accurately model a specific user's finger from lower resolution data. It may also be relevant for inferring the physical properties of the underlying tissue from observing the surface mesh deformations, as previously shown for body tissues [2].

References

[1] Perez, A. G., Lobo, D., Chinello, F., Cirio, G., Malvezzi, M., Martín, J. S., Prattichizzo, D. and Otaduy, M. A. (2017) Optimization-based wearable tactile rendering. IEEE Transactions on Haptics, 10(2): 254–264.

[2] Kim, M., Pons-Moll, G., Pujades, S., Bang, S., Kim, J., Black, M. J. and Lee, S.-H. (2017). Data-driven physics for human soft tissue animation. ACM Transactions on Graphics, 36(4): 54.

Short Biography

After a bachelor degree in Physics, David Gueorguiev completed a Master in computational neuroscience in Paris, and an internship at the Cognition and Brain Sciences Unit in Cambridge on attention and consciousness. During his PhD at Université catholique de Louvain, he studied the perception of natural textures and ultrasonic frictional feedback. In 2016, he became post-doctoral researcher in the MINT team at Inria Lille studying the subjective tactile perception during human-machine interaction. He is now a post-doc in the Haptic Intelligence department at the Max Planck Institute for Intelligent Systems in Stuttgart where he studies finger behaviour during haptic interaction.

Modeling uncertainty to understand biases in tactile localization after brain damage

Yuqi Liu[1]*, Michael Grzenda[1], Jared Medina, PhD[1],

[1] Department of Psychological and Brain Sciences, University of Delaware

Abstract

Humans with S1 lesions demonstrate increased tactile detection thresholds and errors in tactile localization. However, the relationship between detection thresholds, tactile localization patterns and cortical damage has not been systematically examined. We tested over 50 brain-damaged individuals to investigate the relationship between tactile detection and tactile localization. Tactile detection was tested using a staircase procedure with Semmes-Weinstein monofilaments. Tactile localization was tested by stimulating various locations on the dorsal side of the hand with suprathreshold monofilaments, and having participants point to perceived stimulus locations (as in Rapp, Hendel & Medina, 2002). Using linear mixed models, we found that localization percepts on the contralesional, but not ipsilesional hand, significantly shifted towards the center of the hand. Importantly, this central bias increased as detection thresholds increased. Based on a model of spatial memory (e.g. Huttenlocher, Hedges & Duncan, 1991), we hypothesized that the brain utilizes multiple sources of information in tactile localization. With high certainty, we rely on a fine-grained representation of location based on somatosensory input. With high uncertainty, we minimize error by responding closer to the center of the hand (the prototypical representation). Specifically, these sources of information are weighted based on the noise in the sensory input. With increased uncertainty in somatosensation, more weight may be assigned to prototypical information, leading to more central localization percepts. To test this hypothesis, we fitted each individual's data to a model where perceived tactile location is a weighted sum of the actual stimulus location (fine-grained representation) and the location of the hand center (prototypical representation). We found weighting of prototype information significantly correlated with detection thresholds, providing novel evidence for a perceptual mechanism in which cortical damage increases sensory uncertainty, which leads to increased weighting of prototypical versus fine-grained information and a central localization bias.

References

Rapp, B., Hendel, S. K., & Medina, J. (2002). Remodeling of somotasensory hand representations following cerebral lesions in humans. Neuroreport, 13(2), 207-211.

Huttenlocher, J., Hedges, L. V., & Duncan, S. (1991). Categories and particulars: prototype effects in estimating spatial location. Psychological review,98(3), 352.

Short Biography

Yuqi Liu is a fourth-year graduate student in the Cognitive Psychology program, University of Delaware, under the advisement of Dr. Jared Medina. She obtained BS in Psychology from Zhejiang University, China. Her research focuses on how people integrate information from different sensory modalities to form coherent representations of the body. Another line of her research focuses on neural plasticity and behavioral changes in somatosensory representations in brain-damaged individuals.

Markerless tracking of user-defined features with deep learning

Alexander Mathis[1]*, Pranav Mamidanna[1], Taiga Abe[1], Kevin M. Cury[1,3], Venkatesh N. Murthy[2], Mackenzie W. Mathis[1,4,7], Matthias Bethge[1,5,6,7]

[1] Werner Reichardt Centre for Integrative Neuroscience and Institute of Theoretical Physics, University of Tübingen, 72076 Tübingen, Germany
[2] Center for Brain Science and Department of Molecular and Cellular Biology, Harvard University, Cambridge, MA 02138 USA
[3] The Mortimer B. Zuckerman Mind Brain Behavior Institute, Department of Neuroscience, Columbia University, New York, NY, USA
[4] The Rowland Institute at Harvard, Harvard University, Cambridge, MA USA
[5] Max Planck Institute for Biological Cybernetics and Bernstein Center for Computational Neuroscience, Tübingen, Germany
[6] Center for Neuroscience and Artificial Intelligence, Baylor College of Medicine, Houston, TX USA
[7] co-senior authors

Abstract
Quantifying behavior is crucial for many applications in neuroscience. Videography provides easy methods for the observation and recording of animal behavior in diverse settings, yet extracting particular aspects of a behavior for further analysis can be highly time consuming. In motor control studies, humans or other animals are often marked with reflective markers to assist with computer-based tracking, yet markers are intrusive (especially for smaller animals), and the number and location of the markers must be determined a priori. We present a highly efficient method for markerless tracking based on transfer learning with deep neural networks that achieves excellent results with minimal training data. We demonstrate the versatility of this framework by tracking various body parts in a broad collection of experimental settings: mice odor trail-tracking, egg-laying behavior in drosophila, and mouse hand articulation in a skilled forelimb task. For example, during the skilled reaching behavior, individual joints can be automatically tracked (and a confidence score is reported). Remarkably, even when a small number of frames are labeled, the algorithm achieves excellent tracking performance on test frames that is comparable to human accuracy.

References
Mathis A. et al (2018). Markerless tracking of user-defined features with deep learning. arxiv:1804.03142

Short Biography
Alexander Mathis is a postdoctoral fellow in the laboratories of Prof. Venkatesh N. Murthy at Harvard University and Matthias Bethge at the University of Tübingen. He studies motor control and deep learning methods for video analysis in collaboration with Dr. Mackenzie W. Mathis, as well as the sense of smell. Previously he did his PhD in the group of Prof. Andreas V.M. Herz at the University of Munich and worked on deriving tuning properties of grid cells from first principles.

Towards brain-controlled neuromodulation of the cervical spinal cord for the restoration of arm and hand movement in tetraplegia

Matthew G. Perich[1,5*], Beatrice Barra[2,5], Sara Conti[2], Melanie Kaeser[2], Nathan Greiner[2], Jocelyne Bloch[3], Gregoire Courtine[4], Tomislav Milekovic[1,6], Marco Capogrosso[2,6]

[1] University of Geneva, Geneva, Switzerland
[2] University of Fribourg, Fribourg, Switzerland
[3] Centre hospitalier universitaire Vaudois (CHUV), Lausanne, Switzerland
[4] École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland
[5,6] These authors contributed equally

Abstract
For people with high cervical spinal cord injury (SCI), restoring the ability to reach and grasp is the highest priority. However, even the most promising techniques to restore hand and arm function have so far recovered only crude movements. We are working to design and implement a novel neuroprosthetic system for the recovery of hand and arm function after cervical spinal cord injury. Recent advances in brain-controlled neuromodulation of the spinal cord enabled nonhuman primates to regain weight-bearing control of a paralyzed leg as early as 6 days after thoracic SCI [1]. We aim to apply this strategy to the cervical spinal cord to restore hand and arm functions lost after cervical SCI. We trained macaque monkeys to perform a reach, grasp, and pull task while interacting with a robotic arm. We then surgically implanted two Utah electrode arrays in the motor and premotor cortices of the contralateral hemisphere. We recorded neural activity during the unconstrained reaching behavior, along with the full limb kinematics and EMG signals from proximal and distal muscles of the arm. We developed neural decoders to predict motor events related to the reaching and grasping movements using the intracortical recordings. Ultimately, the neural decoders will be linked to spatially-selective cervical spinal stimulation protocols to restore dexterous reaching and grasping movements in nonhuman primates after unilateral cervical SCI.

References
[1] Capogrosso, Milekovic, Borton et al. A brain–spine interface alleviating gait deficits after spinal cord injury in primates. Nature 539, 284-288 (2016).

Short Biography
Matthew Perich earned his Ph.D. at Northwestern University in September 2017. During his graduate work in the lab of Dr. Lee E. Miller, he studied how population activity in motor and premotor cortex allowed for rapid motor adaptation. Upon graduation, he earned a postdoctoral research fellowship from the Whitaker International Program to join the research group of Dr. Tomislav Milekovic at the University of Geneva. Together with Dr. Milekovic, a junior independent researcher, Dr. Perich is currently working on cortically-controlled spinal stimulation, in collaborations with Professor Gregoire Courtine and Dr. Marco Capogrosso.

Wiretapping the brainstem for closing the neuroprosthetic loop: Decoding natural tactile and proprioceptive stimuli, and their peripheral locations, on the dorsal column nuclei surface

Alastair Loutit[1] and Jason R. Potas[1]*

[1] School of Medical Sciences, University of New South Wales, Sydney, Australia.

Abstract

Touch and proprioception are two somatosensory modalities essential for motor control. A dorsal column nuclei (DCN) neuroprosthesis may offer practical solutions for restoring these senses following spinal cord injury.

We aimed to establish the DCN as a potential somatosensory neuroprosthetic target, by showing that responses to natural stimuli in the DCN satisfy key prerequisites. These include demonstration that: 1) DCN responses are predictable and reproducible, yet unique, to peripheral inputs1; 2) DCN signals encode the location, as well as 3) the sensory modality and 4) the sensory quality (i.e. different perceptual experiences within a sensory modality) of somatosensory events arising from the periphery.

Six 8-week-old male Wistar rats were Urethane anaesthetised. Neuronal activity from 7 platinum electrodes, placed on the DCN surface, was recorded during 2 tactile-dominated (20g brush|dowel pokes on the palmer surface of hind- and fore-paws) or 2 proprioceptive-dominated (flexion|extension of hind- and fore-limb joints) natural stimuli.

An artificial neural network (ANN) was trained and tested on 5 DCN signal features, to predict the stimulus location, sensory modality and quality of the 4 natural stimuli presented to the 4 limbs. Machine learnability was derived from the mean of 10 repeated learning-testing cycles.

The trained ANN could correctly discriminate between proprioceptive vs. tactile stimuli with 98.9±0.2% accuracy (chance level (CL), 50%) and among limbs with 98.0±0.4% accuracy (CL, 25%). The mean accuracy for correctly predicting the combined natural stimulus and limb was 87.3±1.9% (CL, 6.5%); accuracy was greater when predicting proprioceptive stimuli (94.5±0.9%, CL 12.5%) compared to tactile (80.1±0.5%).

These findings demonstrate that DCN signals are rich in information that is unique for different tactile and proprioceptive events, and furthermore, their encoding is highly reproducible and predictable within the DCN. These findings support the idea of the DCN as a potential target worthy of further somatosensory neuroprosthetic research.

References

[1] Loutit, A., Redmond, SJ., Maddess, T., Morley, JW., Stuart, G. and Potas, JR. (2017). Characterisation and functional mapping of surface potentials in the rat dorsal column nuclei. Journal of Physiology – London. 595(13):4507-4524

Short Biography

Dr Jason Potas is a neuroscientist interested in somatosensory and motor systems. He received his PhD training at the University of Sydney, Australia, before undertaking post-doctoral studies in various areas relating to neural injury. Before returning to academia at the Australian National University he worked in industry in Brazil, and currently holds a senior lecturer position (neuroanatomy) at the University of New South Wales. Dr Potas leads an independent research team seeking to understand how sensory information is transformed through the nervous system. His laboratory projects, combining neuroscience, machine-learning and biomedical engineering, aim to mimic and/or augment the somatosensory system.

SENSORIMOTOR CONTROL

Neural Correlates of Brain Dynamics Adaptation during Motor Learning

Saeed Babadi[1]*, Shahabeddin Vahdat[2], Theodore Milner[1]

[1] Department of Kinesiology and Physical Education, McGill University
[2] Department of Neurology and Neurological Sciences, Stanford University

Abstract

The central nervous system is able to adapt to a novel physical environment by means of two major control mechanisms. One mechanism is through learning an internal model that generates motor commands to create appropriate forces, and the other is impedance control that modulates the impedance of the limbs and joints by regulating muscle co-contraction. There are different sensorimotor networks involved in modulating each of these control strategies. It has been of great interest to study the neural processes underlying motor adaptation. Nevertheless, there is still substantial conjecture about how these processes are realized in the brain. We investigated this problem using a force field motor adaptation paradigm and resting-state fMRI approach. Participants interacted with a robotic interface which created novel dynamics. Kinematics and electromyography were recorded during four different stages of motor adaptation followed by a resting-state fMRI scan that monitored brain activity immediately after each stage was completed. A metric of muscle co-contraction was computed from the normalized electromyographic signals. Furthermore, motor learning was quantified based on the analysis of catch trials which were placed at the end of each learning phase. We analyzed the functional connectivity in resting-state networks and demonstrated that change in the strength of functional connectivity in certain brain networks including cerebellar, somatosensory, motor and parietal cortical networks was correlated with a metric of co-contraction, and a metric of motor learning. We aim to distinguish between regions of the brain involved in muscle co-contraction (impedance control) and learning to adapt to novel dynamics and propose a control scheme that explains and dissociates the neural correlates of those mechanism as separate control modules. The results of this study can provide new insight into the neural substrates of motor learning and also pave the road for more efficient sensorimotor rehabilitation techniques.

References

Vahdat, S., Darainy M., Milner T., Ostry D. (2011). Functionally specific changes in resting-state sensorimotor networks after motor learning. The Journal of Neuroscience 31(47): 16907-16915.

Franklin D., Osu R., Burdet E., Kawato M., Milner T. (2003). Adaptation to stable and unstable dynamics achieved by combined impedance control and inverse dynamics model. The Journal of Neurophysiology 90: 3270-3282.

Short Biography

Saeed Babadi is a PhD candidate in the Neuromuscular Control Lab at McGill University, under supervision of Dr. Theodore Milner. He received a bachelor's degree in biomedical engineering and a master's in electrical engineering in 2011 and 2014, respectively. His current research is mainly concerned with the analysis of resting-state fMRI in the context of motor learning in order to investigate how different brain regions interact at different stages of the learning. He is also interested in the applications of functional brain imaging to computational and motor neuroscience and how they could develop rehabilitation techniques and neural prosthetics.

Training to improve individuation of finger movements: a pilot study

Jason Friedman[1]*

[1] Tel Aviv University, Tel Aviv, Israel

Abstract

When we try to move or produce force with a single finger, other fingers also move or produce force, a phenomenon known as enslaving (Häger-Ross & Schieber, 2000). Even experts at moving their fingers, such as professional pianists, still show enslaving. Although some enslaving is due to connective tissues between the fingers, it is largely due to neural limitations in individuated finger control. Individuated finger movements are required for many tasks in daily life, such as unbuttoning a shirt, using a smartphone, or unscrewing a lid. In contrast, there are other tasks we perform, such as grasping a cup with the fingertips of the hand, where we apply forces together with multiple fingers. In these cases, the tasks do not require individuated finger movements, but rather coordination of the multiple finger forces. In a pilot study, we trained subjects to improve the individuation of force production by the fingers in an isometric force task. The subjects were instructed to produce a force ramp with an instructed finger and provided with visual feedback, while the other fingers remained also on force sensors, using a well-tested setup (Shaklai, Mimouni-Bloch, Levin, & Friedman, 2017). Following each force ramp, feedback was provided on the activation of the non-instructed fingers, with the participants instructed to minimize force produced by the other fingers. The subjects performed 15 minutes of training on 10 different days. On the first and last days, performance was measured without feedback of the non-instructed fingers. We found that while subjects improved in performing the task (i.e. they were closer to the instructed force ramp with the instructed finger), rather than performing less enslaving after training, the participants produced more enslaving. We will discuss possible explanations for these counterintuitive findings in the context of the competing demands of finger individuation and finger coordination.

References

Häger-Ross, C., & Schieber, M. H. (2000). Quantifying the Independence of Human Finger Movements: Comparisons of Digits, Hands, and Movement Frequencies. Journal of Neuroscience, 20(22): 8542–8550.

Shaklai, S., Mimouni-Bloch, A., Levin, M., & Friedman, J. (2017). Development of finger force coordination in children. Experimental Brain Research, 235(12): 3709–3720.

Short Biography

Jason Friedman is a senior lecturer in the Dept. Physical Therapy & Sagol School of Neuroscience at Tel Aviv University. Originally from Australia, he completed his PhD at the Weizmann Institute in Israel and was a postdoc at Penn State and Macquarie University. His research focuses on motor control of the hand and arm and understanding our amazing manual abilities. His current projects include studies on speeding up the process of motor learning in typical populations and in motor disorders, understanding why we are unable to produce slow, smooth movements, and using arm movements to understand perceptual decision-making processes.

Factors of Impaired Fine Motor Control

Kathrin Allgöwer[1], Waltraud Fürholzer[2], Joachim Hermsdörfer[1*]

[1] Technical University of Munich, Department of Sport and Health Science, Chair of Human Movement Science
[2] kbo-Kinderzentrum München, Munich

Abstract

Our goal was to determine factors which characterize impaired hand function in stroke patients and to analyze the predictive power of the factors with regard to the Jebsen Taylor Hand Function Test (JTHFT) as a common clinical test of fine motor control.

To that aim a test battery was assembled. Bedside the JTHFT, it contained the Nine-Hole Peg Test (9-HPT) and the 2-point discrimination test (2 PD) to obtain a measure of somatosensory loss. To analyze object manipulation skills, grip forces and temporal measures were examined during 1) lifting actions with variations of weight and surface 2) cyclic movements 3) catching tasks assessing predictive and reactive grip force control . Three other aspects of force control included 4) visuomotor tracking 5) fast force changes and 6) grip strength. Twenty-two people following stroke with fine motor deficits and twenty-two healthy controls were examined.

Nine parameters from six tasks were extracted to distinguish significantly fine motor perfor-mance of stroke patients from healthy controls. Using this parameters we identified 3 principal components (factors): 1) Grip force scaling, 2) motor coordination and 3) speed of movement. Interestingly, the two-point discrimination performance as a measure of sensory perception combined with the grip force peaks indicated force economy during object manipulation. Regression analysis found a strong predictability of the performance in the JTHFT based on the three factors ($R2=.687$, $p<.001$).

We revealed specific patterns expressed in three key characteristics of fine motor skills. Somatosensory deficits contribute to a factor expressing motor economy. The factors are able to explain JTHFT results. These findings can serve as a basis for improving diagnostics and enabling more targeted therapy. As shown in a further study, patients with task-related dystonia interestingly exhibit impairments in only one isolated factor (motor coordination).

References

Allgöwer, K. and Hermsdörfer, J. (2017). Fine motor skills predict performance in the Jebsen Taylor Hand Function Test after stroke. Clinical Neurophysiology, 128(10), 1858-1871.

Hermsdörfer, J., Hagl, E., Nowak, D. A. and Marquardt, C. (2003). Grip force control during object manipulation in cerebral stroke. Clinical Neurophysiology, 114(5), 915-929.

Short Biography

Joachim Hermsdörfer is an engineer and received his PhD at the Institute for Medical Psychology in the Ludwig-Maximilians-University Munich. He headed the research group “Sensorimotor Disturbances” in the Clinical Neuropsychology Research Group at Hospital München. In 2010 he was appointed as Full Professor and Chair of Human Movement Science in the Department of Sports and Health Sciences at the Technical University of Munich. His main interest is sensorimotor control in healthy individuals and in patients with neurological diseases. He is studying a variety of motor skills ranging from elementary motor acts to complex tool use. He employs measurements of motor behavior, neuroimaging and neurophysiological methods as well as new technologies in neurorehabilitation.

Neuromuscular control of dexterous finger movements in healthy pianists, pianists with focal dystonia, and non-musicians

Yudai Kimoto[1,2]*, Takanori Oku[2]*, Yuta Furukawa[1,2], Ryuya Tanibuchi[1,2], Masato Hirano[2], Shinichi Furuya[1,2]

[1] Sophia University, Tokyo, Japan
[2] Sony Computer Science Laboratories, Inc. (SONY CSL), Tokyo, Japan

Abstract

Independent control of finger movements plays a key role in hand dexterity. To shed light onto its neuromuscular adaptation mechanisms through extensive training, two studies were performed. The first study compared effects of both neuromuscular control and mechanical coupling on the finger motor independence between healthy pianists and musically-untrained individuals (i.e. non-musicians). Subjects were asked to flex each of the four fingers either voluntarily or passively at three different tempi. We measured angles of the proximal interphalangeal (PIP) and metacarpo-phalangeal (MCP) joints1. We then recorded the maximum force production, the maximum rate of tapping, and the abduction-adduction range of motion for each of the fingers. The movement independence of the index finger when moving at the fast tempo was higher in the pianists than the non-musicians. Neuromuscular constraint to the movement independence of the middle finger when moving at the medium tempo was lower in the pianists than the non-musicians. By contrast, there were no significant group differences in the amount of mechanical coupling between the fingers. With respect to the middle finger of the pianists, there was a negative correlation between the movement independence at the medium tempo and the maximum adduction force level. This observation suggests that extra muscular strength of the finger hinders the independent movement control. The second study investigated neuromuscular hand control of healthy non-musicians, skilled pianists, and pianists with focal hand dystonia (FHD) that involves loss of dexterity of one or more fingers, by recording the EMG of eight hand-intrinsic and extrinsic muscles during playing the piano. An optimization algorithm, an unsupervised clustering, and a regression analysis identified six patterns of the finger muscular coordination that distinctly represent each of FHD and musical expertise, some of which also encoded degradation of motor dexterity in association with FHD. In conclusion, these two studies suggest that reorganization of neuromuscular coordination underlies enhancement and deterioration of the independent movement control through extensive musical training.

References

Lang, CE., Schieber, MH. (2004). Human finger independence: limitation due to passive mechanical coupling versus active neuromuscular control. J Neurophysiol, 92(5):2802-2810.

Short Biography

2018-: Master student, Graduate School of Science and Technology, Sophia University, Tokyo, Japan.
2014-2018: BA of Science, Department of Information and Communication Sciences, Sophia University, Tokyo, Japan.

Manifolds of Natural Hand Representations

Charalambos Harris Konnaris[1,2]*, Aldo Faisal[1,2,3]

[1] Dept. of Bioengineering Imperial College London.
[2] Data Science Institute Imperial College London.
[3] Dept. of Computing Imperial College London.

Abstract

A central question in motor control is to understand how the brain controls and coordinates movement. Specifically in the case of the hand, it is still unclear how the CNS implements this to achieve the multitude of static and dynamic hand poses in every-day life when interacting with objects. It has been shown that hands can be efficiently represented and controlled by a lower dimensional manifold (Santello et al, 1998, Belic & Faisal, 2015). As a result, many bionic and BCI approaches simplify the high dimensional control problem of hand control utilising a lower dimensional manifold. We investigate this control representation by evaluating whether the method of dimensionality reduction (i.e. linear or non-linear) impacts the performance when tele-operating an artificial hand in VR, or whether task performance solely depends on the global reconstruction error of the algorithm and the degree of embedding. Interestingly, in the cases where different algorithms produce similar reconstruction errors, would we expect to see a major impact in human performance? We test our hypothesis using our closed-loop VR platform with the human in the loop. Our platform consists of the following real-time systems: optical motion tracking capturing arm movements, 22 DoF CyberGlove measuring the joint angles of the hand, Physics Engine (Mujoco) allowing real world dynamics and a VR system (HTC Vive) embodying the experience of tele-operating a virtual artificial hand. Using our set-up we can directly measure and compare the performance under various control algorithms for mapping subjects' real hand movements to drive the artificial hand: 1) Direct Control, 2) PCA, 3) Isomap, 4) Sammon Mapping.

References

Santello, M., Flanders and Soechting, F. (1998). Postural Hand Synergies for Tool Use. The Journal of Neuroscience, 18(23):10105-15.

Belic., J., J. and Faisal, A., A. (2015). Decoding of human hand actions to handle missing limbs in neuroprosthetics. Frontiers in Computational Neuroscience, (9): 27.

Short Biography

Upon completion of his BEng in Mechanical Engineering Harris, went on to pursue a Master's degree in Biomedical Engineering at Imperial College London specializing in neurotechnology. Outcomes of his master's thesis include a novel dexterous anthropomorphic robotic hand a patent. Currently, Harris is a PhD student in the Brain and Behaviour Lab at Imperial College. His research focuses on the motor control of human hand. Using data driven approaches from the field of machine learning he is aiming to develop a naturalistic prosthetic hand controller improving human prosthetic hand interaction.

Somatosensory Aspects of Robotic Training for Motor Learning and Neurorehabilitation

Özhan Özen*,[1] Laura Marchal-Crespo[1]

[1] Gerontechnology and Rehabilitation Group, ARTORG Center, University of Bern, Switzerland

Abstract
Robotic systems have rapidly grow popularity in motor learning and neurorehabilitation fields. Robots have relevant advantages when compared to conventional therapy, such as high movement repetition, precise quantitative assessment and rich virtual visuo-haptic environment provision opportunities. Robotic training mainly targets regaining motor skills since robots have the prominent advantage of being able to support the human limbs by applying precise forces. However, another important aspect that has a crucial effect on improving motor skills remains lacking the attention it deserves: sensory training [1].

It cannot be ignored the fact that human motion control is a closed-loop control, i.e. the motor activations of the limbs are based on the somatosensory information they gather. We depend on the signals coming from our moving body parts to be able to navigate and interact within dynamic environments. A number of studies have associated sensory impairment at baseline with poorer motor recovery and function [2]. However, only few studies have examined the role of somatosensory information in robotic assisted neurorehabilitation following brain injuries [3].

Robots provide great opportunities for training sensorimotor skills. We can create virtual environments easily, supplied with intelligently designed visuo-haptic elements that trainees can sense and interact with. This is exactly what this project is about. Using robotic systems, we would like to design and regulate virtual mechanical training environments, which adjust their sensation elements online, according to specific somatosensory skills/deficits of the trainees. We aim to use virtual objects which have high/rich dynamics, surface properties that provide purposeful sensations, and modulate the oscillation dynamics of the environment to train the trainees' sensory system while simultaneously training their motor system. We believe this research has a great potential to impact the field of robotic neurorehabilitation.

References
[1] N. Bolognini, C. Russo, and D. J. Edwards, "The sensory side of post-stroke motor rehabilitation," Restor. Neurol. Neurosci., 34(4): 571–586, 2016.

[2] S. Meyer, A. H. Karttunen, V. Thijs, H. Feys, and G. Verheyden, "How do somatosensory deficits in the arm and hand relate to upper limb impairment, activity, and participation problems after stroke? A systematic review," Phys. Ther., 94(9):1220–1231, Sep. 2014.

[3] J. B. Rowe, V. Chan, M. L. Ingemanson, S. C. Cramer, E. T. Wolbrecht, and D. J. Reinkensmeyer, "Robotic Assistance for Training Finger Movement Using a Hebbian Model: A Randomized Controlled Trial," Neurorehabil. Neural Repair, 31(8): 769–780, Aug. 2017.

Short Biography
Özhan Özen was born in Istanbul in 1992. He received his B.S. degree in Mechatronics Engineering from Sabanci University, Istanbul (2015) and his MSc degree in Robotics, Systems & Control from ETH Zurich (2017).

He started his PhD in Biomedical Engineering at the ARTORG Center, University of Bern, under the supervision of Laura Marchal-Crespo in 2017. His focus is making the robotics systems intelligent, adaptive and autonomous for neurorehabilitation.

Laterality Differences in Human Hand Kinematics (and Grasping-Related Dimensionality Effects)

Tomke Schoss[1, 2]*, Andrej Filippow[1], Hansjörg Scherberger[1, 2]

[1] Neurobiology Laboratory, German Primate Center, Göttingen, Germany
[2] Faculty of Biology and Psychology, Georg August University, Göttingen, Germany

Abstract

Humans use their hands effortlessly for their daily tasks. The loss of an upper limb has a large impact on an individual's life and current prostheses can restore only very basic functions. Thus, a better understanding of human hand kinematics would help to improve prostheses. Therefore, a human data glove was developed based on an previous glove system originally developed for primates, which uses only seven sensors (compared to 18-22 sensors in commercially available data gloves), is able to track 32 degrees of freedom in real-time, and can represent the movements in a 3-D model on a screen (Schaffelhofer & Scherberger 2012). The human data glove was developed with relatively normal haptics and no range restrictions to allow natural interactions and movements.

Humans mostly prefer one hand over the other, in particular for fine, dexterous movements. Here we investigate whether this preference has an effect on hand kinematics using a free natural hand movement task (e.g., gestures) in healthy, right handed subjects (N=30). Principal component analysis (PCA) is employed to characterize the most frequently used movement components in each subject to compare the features in the dominant and non-dominant hand. Furthermore, this analysis will also reveal specific couplings of joints kinematics, which will be tested for laterality differences.

In a second experiment, we want to add to the increasing interest in virtual reality (VR) that requires more possibilities to interact with objects in the VR. The question arises, how hand postures differ between real object and imagined object interactions. Therefore, a grasping task with objects of daily life (e.g. coffee mug) was designed with two conditions: "pantomime (VR) grasp" and "real object grasp". Data from N=30 healthy, right handed subjects are compared across these two conditions to investigate possible dimensionality effects during real vs. imagined object interactions.

NOTE: This study is an ongoing master thesis project with submission in August 2018.

References

Schaffelhofer, S., and Scherberger, H. (2012). A new method of accurate hand- and arm-tracking for small primates. Journal of Neural Engineering 9:1-13.

Short Biography

Tomke Schoss achieved her B.Sc. in Biology in June 2015 and now pursues her M.Sc. at Göttingen University, where she became interested in human neurophysiology and neuroprosthetics and learned various methods (e.g. TMS, fMRI, EEG, EMG based electrode prostheses liner). By joining the Neurobiology laboratory at the German Primate Center (Göttingen, Germany) within her Neural- and Behavioral Biology Master Program (M.Sc. 08/2018), she now focuses on hand kinematics and brain computer interface (BCI). From autumn on, she will do her PhD in the field of human hand electrophysiology with additional S1-implantations for sensory feedback.

PARTICIPANTS

Last Name, First Name(s)	Email	ID	Page
Afzal, Naqash	h.afzal@student.unsw.edu.au	C01P	79
Aglioti, Salvatore Maria	salvatoremaria.aglioti@uniroma1.it	KEYNOTE	22
Alluri, Sindhu Reddy	sanq5@mst.edu	C02P	80
Andersen, Richard	andersen@vis.caltech.edu	KEYNOTE	15
Auepanwiriyakul, Chaiyawan	ca1216@ic.ac.uk	D01P	93
Babadi, Saeed	saeed.babadi@mail.mcgill.ca	E01P	101
Bensmaia, Sliman	sliman@uchicago.edu	KEYNOTE, A03T	10, 20
Birznieks, Ingvars	i.birznieks@unsw.edu.au	KEYNOTE, A04P, C01P	11, 64, 79
Brickwedde, Marion	marion.brickwedde@rub.de	C03P	81
Brugger, Peter	peter.brugger@usz.ch	KEYNOTE, B06T, B10P	4, 33,76
Buchwald, Daniela	dbuchwald@dpz.eu	A01P	61
Chen, Daofen	chend@ninds.nih.gov		
Clark, Gregory	Greg.Clark@utah.edu	KEYNOTE	48
Conti, Fabio Mario	f.conti@clinica-hildebrand.ch		
Cruz, Thalita	thalita.cruz@gmail.com	B01P	67
Delhaye, Benoit	delhayeben@gmail.com	A03T	20
Dempsey-jones, Harriet	h.dempseyjones@gmail.com	B05T	32
de Vignemont, Frederique	fvignemont@gmail.com	KEYNOTE	30
Dinse, Hubert	hubert.dinse@rub.de	KEYNOTE, B02T, C03P, C05P, C07P	35, 26, 81, 83, 85
Edmondson, Laura	lredmondson1@sheffield.ac.uk	D05T	51
Faisal, Aldo	Aldo.faisal@imperial.ac.uk	KEYNOTE, D03T, D01P, E05P	19, 49, 93, 105
Farnè, Alessandro	alessandro.farne@inserm.fr	B02T, B07P	26, 73
Fischer, Martin	martinf@uni-potsdam.de	KEYNOTE	23
Foerster, Francois	francois.foerster@plymouth.ac.uk	B02P	68
Franck, Johan Anton	h.franck@adelante-zorggroep.nl		
Friedman, Jason	jason@tau.ac.il	E02P	102
Friesen, Rebecca	r-fentonfriesen@u.northwestern.edu	C04P	82
Fuchs, Xaver	xaver.fuchs@uni-bielefeld.de	B03T	27
Furukawa, Yuta	yuta.vn10@gmail.com	E02T, E04P	57, 104
Furuya, Shinichi	furuya@csl.sony.co.jp	E02T, E04P	57, 104
Gassert, Roger	roger.gassert@hest.ethz.ch	KEYNOTE	54
Gaunt, Robert	rag53@pitt.edu	KEYNOTE	45
Gindrat, Anne-Dominique	AGindrat@dpz.eu	A02P	62
Giurgola, Serena	s.giurgola@campus.unimib.it	B02P	69
Guémann, Matthieu	matthieu.guemann@u-bordeaux.fr	D02P	94
Gueorguiev, David	dgueorguiev@is.mpg.de	D03P	95
Guidali, Giacomo	g.guidali@campus.unimib.it	A05P	65
Hartcher-O'Brien, Jess	j.hartcher-obrien@tudelft.nl	A03P	63
Hayward, Vincent	hayward@cim.mcgill.ca	KEYNOTE, A03P, B07P	4, 24, 38, 63, 73
Hepp-Reymond, Marie-Claude	mchr@ini.uzh.ch		
Hermsdörfer, Joachim	Joachim.Hermsdoerfer@tum.de	E03P	103
Hirano, Masato	hiraramasa@gmail.com	E02T, E04P	57,104
Huber, Daniel	daniel.huber@unige.ch	KEYNOTE	18
Johansson, Roland	roland.s.johansson@umu.se	KEYNOTE	12
Konik, Stephanie	stephanie.konik@epfl.ch		

Last Name, First Name(s)	Email	ID	Page
Kaas, Amanda	a.kaas@maastrichtuniversity.nl	A02T	16
Kaelin, Alain	alain.kaelin@eoc.ch	KEYNOTE	36
Kamper, Derek	dgkamper@ncsu.edu	KEYNOTE	56
Kieliba, Paulina	ucjupki@ucl.ac.uk	B04P	70
Kikkert, Sanne	sanne.kikkert@hest.ethz.ch	B05P	71
Kimoto, Yudai	yudai.k36@gmail.com	E02T, E04P	57, 104
Konnaris, Charalambos	charalambos.konnaris14@imperial.ac.uk	E05P	105
Krubitzer, Leah	lakrubitzer@gmail.com	KEYNOTE	6
Krüger, Marie	marie.krueger@rub.de	C05P	83
Kuchenbecker, Katherine J.	kjk@is.mpg.de	KEYNOTE, D05P	37, 95
Kuehn, Esther	esther.kuehn@dzne.de	A01T	14
Lambercy, Olivier	olivier.lambercy@hest.ethz.ch	KEYNOTE	54
Liu, Yuqi	yliu@psych.udel.edu	C06P	84
Macchione, Silvia	silvia.macchione@inserm.fr	B02T, D04P	26, 96
Maimon-Mor, Roni	ronimaimon@gmail.com	B06P, B10P	72, 76
Makin, Tamar	tamarmakin@gmail.com	KEYNOTE, B05T, B04P, B05P, B06P, B10P	28, 32,70,71,72,76
Mastria, Giulio	giulio.mastria@chuv.ch		
Mathis, Alexander	amathis@fas.harvard.edu	D05P	97
Mathis, Mackenzie	mathis@rowland.harvard.edu	KEYNOTE, D05P	17, 97
Medina, Jared	jmedina@psych.udel.edu	C05P, D04P	84, 96
Micera, Silvestro	silvestro.micera@epfl.ch	KEYNOTE, D02T	42, 44
Milekovic, Tomislav	tomislav.milekovic@unige.ch	D06P	98
Miller, Lee	lm@northwestern.edu	KEYNOTE, D03T, E03T	46, 49, 58
Miller, Luke	luke.miller@inserm.fr	KEYNOTE, B07P	24, 73
Muret, Dollyane	dollyane.muret@gmail.com	B02T, C07P	26, 85
Nakatani, Masashi	mn2598@sfc.keio.ac.jp		
Oku, Takanori	t.oku0222@gmail.com	E02T, E04P	57, 104
Özen, Özhan	oezhan.oezen@artorg.unibe.ch	E06P	106
Paclet, Florent	florent.paclet@u-bordeaux.fr	D02P	94
Perich, Matthew	matthew.perich@unige.ch	D06P	98
Peviani, Valeria Carmen	valeria-carmen.peviani@ae.mpg.de	B08P	74
Potas, Jason	j.potas@unsw.edu.au	D07P	99
Puts, Nicolaas	nickputs@gmail.com	C08P	86
Rinderknecht, Mike Domenik	mike.rinderknecht@hest.ethz.ch	KEYNOTE	54
Rusconi, Elena	elena.rusconi@unitn.it	B01T	25
Sangwook, Oh	sangwook05@hanmail.net		
Sarlegna, Fabrice	fabrice.sarlegna@univ-amu.fr	KEYNOTE	29
Saetta, Gianluca	gianluca.saetta@usz.ch	B06T, B09P	33, 75
Sanchez, Ramon	ramonsc@bu.edu		
Sburlea, Andreea Ioana	andreea.sburlea@tugraz.at	E01T	55
Scherberger, Hans	hscherberger@dpz.eu	KEYNOTE, A01P, E07P	13, 61, 107
Schone, Hunter	hunter.schone.16@ucl.ac.uk	B10P	76
Schoss, Tomke	t.schoss@gmail.com	E07P	107
Scott, Stephen	steve.scott@queensu.ca	KEYNOTE	53
Seo, Na Jin	seon@musc.edu	C10P	88
Striem-Amit, Ella	striemamit@fas.harvard.edu	B04T	31
Tamè, Luigi	luigi.tame@gmail.com	B11P	77
Tee, Benjamin C.K.	benjamin.tee@nus.edu.sg	D01T	43
Thomas, Felix	felix.thomas@balgrist.ch	C01T	39
Tyler, Dustin	dustin.tyler@case.edu	KEYNOTE	47
Valle, Giacomo	vallegiacomo@gmail.com	D02T	44
Vardar, Yasemin	yvardar@is.mpg.de	C11P	89

Last Name, First Name(s)	Email	ID	Page
Versteeg, Chris	christopherversteeg2020@u.northwestern.edu	E03T	58
Vickery, Richard	richard.vickery@unsw.edu.au	KEYNOTE, A04P, C04P	11, 64, 79
Visell, Yon	yonvisell@ece.ucsb.edu	C02T	40
Wesselink, Daan B.	dwesselink@gmail.com	B05T	32
Wilf, Meytal	meytalwilf@gmail.com		
Wu, Yufei	yufei.wu13@imperial.ac.uk	D03T	49
Yau, Jeffrey	jeffrey.yau@bcm.edu	D04T	50
Zbytniewska, Monika	monika.zbytniewska@hest.ethz.ch		
Zoller, Esther	esther.zoller@unibas.ch	C13P	91
Zöller, Aaron	aaron.zoeller@psychol.uni-giessen.de	C12P	90