

SMC 2015

February 20th-21st
University of Queensland, Brisbane



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Abstracts

Sensorimotor Control Meeting
2015

Sensorimotor Control Meeting 2015

Time	Friday 20th	Saturday 21st
8:30am	Registration & Coffee (AEB Building)	Arrive & Coffee (AEB Building)
8:45am	Welcome	Plenary 3- Jerry Loeb Representing the World in the Brain: Reverse Biomimetic Design from Haptic Robots
9:00am	Plenary 1 – Peter Silburn Surfing Brain Waves in Disorders of Movement	
9:30am	Symposium 1 (6 x 15min) Clinical Studies and Pain Marinovic, Bergin, Singh, Pegoraro, Kavanagh, Hodges	Symposium 4 (6 x 15min) Young Investigator Session Selvanayagam, D'Amico, Poh, Kennedy, Reissig, Jones
11:00am	Morning Tea	Morning Tea
11:30am	Symposium 2 (6 x 15min) Posture, Locomotion and Exercise Hudson, Coxon, Rouffet, Garland, Roeder, Boonstra	Symposium 5 (6 x 15min) Coordination and Somatosensory Function Birznieks, Redmond, van den Hoorn, Hug, O'Dwyer, Allen
1:00pm	Lunch	Lunch
2:00pm	Plenary 2 – John Rothwell Anatomical and functional anisotropy of human motor cortex	Plenary 4 – Jason Mattingley Eye movements and visual stability
2:30pm	Symposium 3 (6 x 15min) Sensorimotor Adaptation Salomoni, Chye, Nuzzo, Baarbé, Leow, Stöckel	Symposium 6 (6 x 15min) Sensorimotor Learning and Plasticity Burns, Mehrkanoon, Xu, Vallence, Bradnam, Wallis
4:00pm	Poster Session With afternoon tea	Closing remarks (YIA Award) Followed by afternoon tea
6:00pm	Drinks and dinner in the Terrace Room, Sir Lew Edwards Building	

Plenary Speakers Friday 20th



Prof. Peter Silburn

Surfing Brain Waves in Disorders of Movement

Peter Silburn, Professor of Clinical Neuroscience at The University of Queensland

Prof. Silburn's research into deep brain stimulation is changing the lives of patients with Parkinson's disease, as well as a range of other neurodegenerative diseases, such as Tourette's syndrome, essential tremor and dystonia.

In collaboration with neurosurgeon Dr Terry Coyne, Peter leads one of the busiest clinical neurosciences units in Australia.



Prof. John Rothwell

Anatomical and functional anisotropy of human motor cortex

John Rothwell, Institute of Neurology, University College London

Prof Rothwell's work has provided insight into the mechanisms of action of deep brain stimulation for the treatment of Parkinson's disease and dystonia and the disorganisation of cortical and brainstem circuitry in different forms of myoclonus. In addition, his lab has extensive experience in the use of transcranial magnetic stimulation (TMS) and has pioneered its use to study cortical connectivity, as a virtual lesion technique and as a method for provoking long-term changes in the excitability of cortical synapses. This approach gives insight into how the remainder of the brain reacts to changes in

function of another part, as well as to possibilities for its therapeutic application in rehabilitation of brain injury or chronic disease.

Plenary Speakers Saturday 21st



Prof. Gerald Loeb

Representing the World in the Brain: Reverse Biomimetic Design from Haptic Robots

Gerald Loeb, Department of Biomedical Engineering, University of Southern California

Prof. Loeb works on neural prosthetics - interfaces between electronic devices and the nervous system that are used to replace sensory and motor functions and correct dysfunctions in people with neurological problems. He was one of the developers of the cochlear implant now used to restore functional hearing to the deaf and continues to pursue improvements in this mature technology. Computer models based on experimental data from muscles, motoneurons and proprioceptors are being developed to test new theories of control that may permit the reanimation of paralyzed limbs via functional electrical stimulation (FES). Similar models and interfaces are also being applied to the design and control of powered prosthetic arms and hands.



Prof. Jason Mattingley

Eye movements and visual stability

Jason Mattingley, Queensland Brain Institute and School of Psychology, University of Queensland

Professor Mattingley's research is directed toward understanding the neural and cognitive mechanisms that underlie selective attention. His work includes the study of individuals with acquired and developmental disorders of attention, such as spatial neglect and attention deficit hyperactivity disorder (ADHD) using functional brain imaging techniques such as fMRI and scalp-recorded electrical potentials. His work has important implications for a number of real-world endeavours, including the diagnosis and treatment of individuals with attention deficits; the design of more efficient systems for conveying information to human operators; and in helping to predict preference and choice in consumer behaviour.

Anatomical and functional anisotropy of human motor cortex

John Rothwell, Vishwal Rawji, Ricci Hannah & Masashi Hamada

UCL Institute of Neurology, London, UK

Ever since the introduction of TMS it has been known that different directions of current activate the motor cortex in different ways. A posterior-anterior (PA) induced current evokes the lowest threshold responses, whereas the opposite orientation (anterior-posterior, AP) has a higher threshold, and produces responses that have a longer latency. Several lines of evidence including recordings of descending activity recorded from the spinal epidural space and single unit EMG recording from muscle suggest that PA and AP stimuli activate different sets of inputs onto the corticospinal neurones. The aim of our present studies is to test whether these inputs play different functional roles in movement control and whether they respond differentially to repetitive stimulation protocols designed to induce short term plasticity.

In a recent paper (Hamada et al (2014): *JNeurosci* 34, 12837) we found that a protocol that preconditioned PA-sensitive inputs could influence the rate of learning in a ballistic thumb abduction task whereas performance was unaffected by preconditioning AP-sensitive inputs. Conversely, preconditioning AP-sensitive inputs affected learning in a visuo-motor task whereas PA-sensitive inputs had no effect. Notably, despite the different effects on behaviour, both forms of preconditioning had similar effects on the MEP. The conclusion was that these two sets of inputs, which by chance are differentially sensitive to directional TMS, participate preferentially in different types of motor behaviour.

More recently we have explored the relative sensitivity of these circuits to TDCS. In 15 healthy volunteers, we applied TDCS via two electrodes placed 3cm in front and 3cm behind the motor hotspot for the hand. The electrodes were positioned individually to align with the preferred orientation of PA TMS. Stimulation was applied at 1mA for 10min and MEPs evoked by PA TMS pulses were measured before and at 10min intervals afterwards. TDCS with a posterior anode suppressed MEPs to 75% of control values, whereas TDCS with a posterior cathode had no significant effect. A second experiment showed that stimulation parallel to the line of the central sulcus (medial-lateral) also had no effect on MEPs. A final experiment compared the effect of TDCS with a posterior anode on MEPs evoked by both PA and AP TMS. Only MEPs evoked by PA stimulation were suppressed by preconditioning with a posterior anode.

The hand area of motor cortex is highly sensitive to the direction of induced current flow, both with TMS and TDCS. This is relevant both physiologically in terms of effects on MEP, as well as behaviourally in terms of motor learning. However, the behavioural effect may be unrelated to effects on MEP, indicating that the latter cannot be used to predict the behavioural relevance of a plasticity protocol.

Representing the World in the Brain:

Reverse Biomimetic Design from Haptic Robots

Gerald E. Loeb, M.D., Professor of Biomedical Engineering, University of Southern California, and CEO of SynTouch LLC, Los Angeles.

Figuring out how the brain works by observation has proven difficult. Some progress has been made interpreting preprogrammed motor behaviors by analogy to engineered machines (e.g. oscillators and servocontrollers). Some progress has been made on low-level sensory perception by building biomimetic models based on biological transduction and neural networks. But most cognitive behaviors are too complex to train and involve too many heterogeneous neural structures to probe (at least until the new US BRAIN initiative saves us all). We have stumbled onto another strategy in which we assemble engineered systems from biomimetic components, compare their emergent behaviors to biological organisms, and evolve plausible hypotheses about how both could work. We were forced into this after we developed a highly biomimetic tactile sensor and had to figure out what to do with it. Unlike vision or hearing, you can't get anything from a tactile sensor without executing exploratory movements. The sensory data then depend on the nature of the movement and the properties of the sensor as well as the properties of the unknown object. This turns out to be an impossible problem to solve by deconvolution of random movements, so the learning, selection, sequencing and control of those movements must be an integral part of the cognitive process. This is the classical "action for perception" problem. We extended Bayesian inference to make those decisions and we achieved (super)humanlike performance identifying textured objects from a set of 117 previously experienced objects. We then realized that our database of prior experience could itself be searched to solve two obverse classical problems: i) figuring out how to handle an unknown object to achieve a particular function (perception for action), and ii) identifying the functions that a known object might subservise (Gibsonian affordance). The steps for acquiring, organizing and utilizing information about the external world appear to generalize well across all sensory modalities. They also lend themselves to decomposition into subsystems that are consistent with current hypotheses about the function of many individual parts of the nervous system. We hope that such grand theorizing by analogy will be useful for neuroscientists. We know that it leads to surprisingly effective machines.

Further Reading: Loeb, G.E. and Fishel, J.A. Bayesian Action&Perception: Representing the World in the Brain, *Frontiers in Neuroscience* **8**:341, doi: 10.3389/fnins.2014.00341, 2014, <http://journal.frontiersin.org/Journal/10.3389/fnins.2014.00341/abstract>.

Eye movements and visual stability

Jason B. Mattingley
The University of Queensland
St Lucia, Queensland, Australia

Humans, like many animals, use eye movements to selectively sample the visual environment, bringing objects of interest onto the fovea for fine-grained analysis. Each time a saccade is made, the retinal image is abruptly displaced. The challenge for the visual system is to maintain perceptual stability in the face of such displacements. One way in which stability might be achieved is by using information about the direction and extent of an impending saccade to update internal representations of the locations and features of objects in the visual world. Neurons at various levels of the visual system, including the midbrain, parietal and prefrontal cortices, alter their responses if an impending saccade will bring a stimulus into their receptive field. Such changes in neural activity provide a potential mechanism for ensuring visual stability across saccades. In this talk I will discuss work in which we have shown that object perception in peripheral vision is enhanced at the goal of an intended saccade, and that pre-saccadic updating preserves the elementary features of objects at their predicted post-saccadic locations. Our findings suggest a mechanism by which object recognition might be enhanced in the periphery during active search of visually cluttered environments.

Symposium 1: Clinical Studies and Pain

Session Chair: Guy Wallis

9:30	Welber Marinovic	The facilitation of motor actions by accessory sensory stimulation during movement preparation
9:45	Michael Bergin	Altered movement variability in chronic lateral epicondylalgia
10:00	Surya Singh	Adaptive selective fast motion correction methods to support super-accurate targeting in deep brain stimulation
10:15	Roger Pegoraro	Cortical oxygenation response to autonomic challenge in Parkinson's disease
10:30	Justin Kavanagh	Resistance training reduces force tremor in Essential Tremor patients
10:45	Paul Hodges	Motor control changes with pain/injury, but don't forget the muscle

The facilitation of motor actions by accessory sensory stimulation during movement preparation.

Welber Marinovic^{1,2}, Sandra Brauer³, Timothy Carroll¹, Stephan Riek¹

1. School of Human Movement Studies and Nutrition, University of Queensland

2. School of Psychology, University of Queensland

3. School of Health & Rehab Sciences

Introduction: There has been an increasing interest in the use of loud acoustic stimulation (LAS) to gain further insight into the preparation and initiation of motor actions. Typically, LAS presentation during the preparation for an upcoming movement culminates in the earlier than normal initiation of the prepared action as well as an increase in response magnitude. Recent reports have shown that LAS can also facilitate movement initiation and execution in chronic stroke survivors (Honeycutt & Perreault, 2012; Honeycutt, Tresch, & Perreault, 2015), suggesting that current therapies for movement recovery might benefit from employing alternate methods of triggering movement. Here we sought to offer a new way to facilitate motor actions that could be of relevance in clinical settings.

Methods: In Experiment 1, healthy young participants performed an arm supination action in response to a visual go-signal. In some trials, we presented either an auditory or electric stimulus in synchrony with the presentation of the go-signal. In Experiment 2, healthy participants performed a finger abduction action in sync with the predicted time of appearance of the last of a sequence of four flashes on a monitor screen. Occasionally, acoustic, electric or combined stimulation were presented 200 ms prior to the expected time of movement onset. In Experiment 3, five chronic stroke patients performed a reaching task in response to a visual go-signal. Acoustic and electric stimuli were used as in Experiment 1.

Results: We found that electric stimulation can be as effective as acoustic stimulation in facilitating motor actions in both reaction time and anticipatory timing tasks. Our results also showed that the effects of acoustic and electric stimulation can be combined to elicit a release of anticipatory actions that is faster than in response to either acoustic or electric stimulation alone. Finally, our preliminary data with chronic stroke patients showed that their responses were faster and initiated much earlier than normal in the presence of both types of sensory stimulation.

Discussion: Our results reveal two similarities between the classic startle-reflex (e.g. eye-blink) and the early release of motor actions by sensory stimulation. First, an electric stimulus can also trigger prepared responses. Second, the use of cross-modal stimulation can increase the magnitude of the response. These findings may lead to new avenues for experimental and clinical exploitation of the effects of sensory information on movement preparation and initiation.

References

Honeycutt, C. F., & Perreault, E. J. (2012). Planning of Ballistic Movement following Stroke: Insights from the Startle Reflex. *PLoS ONE*, 7(8), e43097. doi: 10.1371/journal.pone.0043097

Honeycutt, C. F., Tresch, U. A., & Perreault, E. J. (2015). Startling acoustic stimuli can evoke fast hand extension movements in stroke survivors. *Clinical Neurophysiology*. doi: <http://dx.doi.org/10.1016/j.clinph.2014.05.025>

Altered movement variability in chronic lateral epicondylalgia

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Introduction: The goal of motor tasks can be maintained despite variability in the multiple degrees of freedom (e.g. motion of body segments/joints and muscle activity) involved in the task. Variation in these elements of a task ($VAR_{elements}$) might be important to distribute stresses between tissues to reduce cumulative loading. Changes to $VAR_{elements}$ in the presence of chronic pain have been considered during complex, multi-joint tasks, and results have been contrasting; e.g. reduced shoulder $VAR_{elements}$ during reaching vs. increased knee $VAR_{elements}$ during walking. This difference may be explained by the capacity of a specific task element to be varied. Some task elements may be tightly constrained by the nervous system and not able to change, whereas other may be more flexible. Pain may induce different effects on variation in these two contexts. One way to consider this possibility is to study simple motor tasks that by nature have few degrees of freedom and limited capacity to change e.g. wrist radial-ulnar deviation. We aimed to determine whether people with chronic lateral epicondylalgia (LE; ‘tennis elbow’) demonstrate; (i) altered $VAR_{elements}$ during a simple radial-ulnar deviation task that can be performed with differing degrees of pain provocation (elements were considered to be the possible motion in the planes other than the primary movement direction: flexion-extension, pronation-supination); (ii) whether pain intensity affects magnitude of $VAR_{elements}$; and (iii) whether $VAR_{elements}$ changes over time with repetition of the task.

Methods: Twenty participants with chronic LE were matched for age, sex, and hand-dominance to twenty healthy controls. Participants performed 60 radial-ulnar deviation movements between two target angle regions for two tasks. Movements of the affected wrist and forearm were recorded with a 3D motion analysis system. Task 1 involved radial-ulnar movement with the elbow extended whilst gripping a load cell at a standardised force, with the intention to provoke pain in participants with chronic LE. Task 2 involved radial-ulnar movement with the elbow flexed and the hand relaxed (i.e. no grip). After each set of 20 movements LE participants verbally rated their pain intensity on an 11-point numerical rating scale (NRS: 0-10). $VAR_{elements}$ was measured as the standard deviation (SD) of angular motion in flexion-extension and pronation-supination. Pain intensity and SD data were compared between the *start* (repetitions 1-20) and *end* (repetitions 41-60) of the trial, and between Groups with repeated measures ANOVAs for each Task.

Results: Pain intensity increased between the *start* and *end* of the trials for the provocative Task 1 (Start: $2.9 \pm 0.6/10$; End: $4.5 \pm 0.9/10$; $p < 0.001$) and Task 2 (Start: $0.5 \pm 0.4/10$; End: $1.0 \pm 0.7/10$; $p = 0.012$). Although there was no difference in SD between LE and Controls in Task 1 or Task 2 ($p > 0.20$), in Task 1, SD of flexion-extension decreased between the *start* and *end* of the trial for the LE group ($p = 0.008$), but not Controls ($p = 0.43$). SD of pronation-supination did not change for either group ($P > 0.28$). In Task 2, there was no change between the *start* and *end* of the trial for either group or direction of movement (all $P > 0.19$).

Discussion: $VAR_{elements}$ was not less in chronic LE than painfree controls during a simple radial-ulnar deviation task that evoked moderate or minimal pain, but did undergo greater reduction over time during repeated performance. One interpretation is that participants decreased $VAR_{elements}$ to constrain movement with repetition and limit potential for pain to increase from variation into a more provocative option, which could be possible if variation was increased.

Adaptive Selective Fast Motion Correction Methods to Support Super-Accurate Targeting in Deep Brain Stimulation

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Introduction

Subthalamic nucleus (STN) Deep Brain Stimulation (DBS) is a treatment of symptoms in patients with advanced Parkinson disease. Its neurosurgery involves deep needle insertions to the STN at 60-70mm from the skull. Clinical outcomes critically depend on targeting accuracy.

While stereotactic (Leksell) frames may be used, this assumes that variations from pre-operative imaging/planning are negligible. Directly sensing and tracking the tip location *in vivo* with high-resolution imaging techniques (e.g., X-ray) is complicated, unsafe, expensive and not always possible. Thus, considerable attention has been focused on modelling both the dynamics of the needle and the needle-tissue interaction and using this in a model-predictive manner. Coupled with this is the use “feedback control” to steer around critical tissue and back to target points.

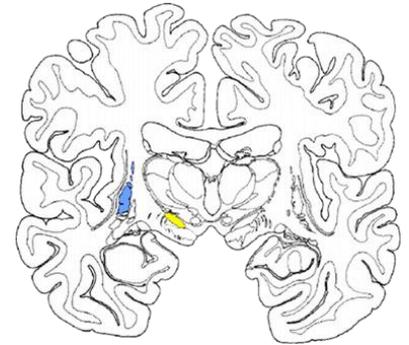


Figure 1 Illustration showing the depth of the STN (yellow). Insertion has to avoid critical neighbouring tissue (e.g., putamen (blue)).

Methods

We consider the use of Fast Motion Correction methods from robotics to compute sub-mm accurate trajectories for targeting tissue that compensate for both needle and tissue deformation during the insertion procedure. The algorithm extends on motion planning methods by exploiting the kinematic structure of the trajectory (ie, that it is embed in SE(3) or the special Euclidean group in 3D-space). This allows one to efficiently adapt small key segments of a given trajectory rather than start anew. Unlike a regulator (that seeks to minimise error), this approach seeks to drive a system to a final intersection with the tissue target while respecting (internal) dynamic and (external) environmental/obstacle constraints. This framework also allows for the computation of a metric on the likelihood of deviation, which is an additionally beneficial statistic for guided operations. Such a ranking mechanism is unique in that it does not need to assume static properties and models the total continuum.

Results

The Fast Motion Correction method was simulated for a needle steering and targeting case. A typical result of the method is shown in Figure 2. Here a needle needs to reach the goal (*dot*) and has an initial plan (*dashed line*). An offset error (*dotted line*) results in it colliding with a critical structure (*sphere*). The solid line is the correction made by the Fast Motion Correction method.

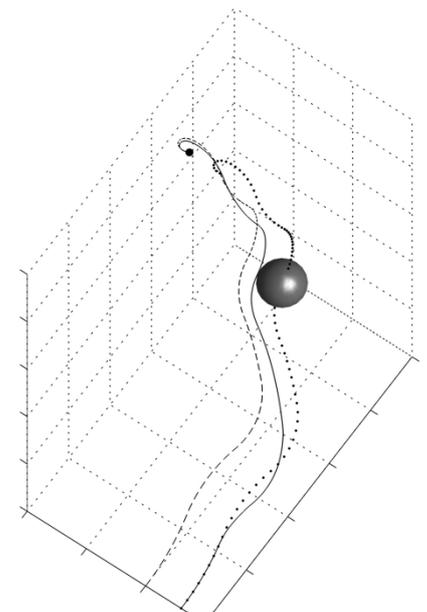


Figure 2 Sample result of the Fast Motion Correction planner correcting for a large initial deviation (dashed line to dotted line) by updating key segments to not only reach the target but avoid critical structures (shown as a sphere)

Discussion

The insertion of highly-flexible MicroTargeting electrodes for Deep Brain Stimulation may be assisted by an approach that can handle the dynamic nature of the environment (neural tissue, for example, can compress and displace by 2 cm [30]), the variation in tissue parameters and the miniature scale (200 μm OD), all of which exceed the limits of state-of-the-art needle steering systems.

Fast Motion Correction provides a mechanism to compute these interception trajectories in real-time and with sub-mm targeting accuracy.

Cortical oxygenation response to autonomic challenge in Parkinson's disease

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Introduction: Although Parkinson's disease (PD) is considered a movement disorder, autonomic dysfunction is common for those with this condition. Dysautonomia can precede the onset of movement difficulties by up to 5 years [1]. One consequence arising from autonomic inefficiency is dysregulation of blood pressure (BP) and heart rate (HR) which can result in orthostatic hypotension (OH). OH has a negative effect on gross motor skill, postural stability and cognition [2]. Cortical oxygenation changes in response to autonomic challenge in a neurologically normal population [3]. However, the cortical oxygenation response during assessment of autonomic function in PD is unknown. The purpose of this study was to investigate the blood oxygenation response for the prefrontal cortex of the brain to passive changes in posture for people with PD.

Methods: 12 early stage PD patients (UPDRS 37.0±17.5) and 12 age matched healthy adults (CON) without dementia (Addenbrooke's >87) underwent a head up tilt test (HUTT) to assess autonomic function. Participants rested supine for 5 min after which they were passively tilted to an upright position for 10 min before being passively returned to supine. Blood oxygenation (OHb) and deoxygenation (HHb) concentration of bilateral frontal cerebral cortices was assessed using functional Near Infrared Spectroscopy (fNIRS) (NIRO 200, Hamamatsu Photonics, Japan). BP (Finapres, The Netherlands), and HR (ADInstruments, New Zealand) were continuously recorded.

Results: There were no significant differences in age (PD 69.1±6.04 yrs; CON 70.3±1.97) or cognition (Addenbrooke's: PD 90.4±11.11; CON 95.9±2.11) between groups. Passive postural change caused responses of differing magnitude and time course between groups for BP, HR and cortical oxygenation. Further, while variability for BP and HHb was small it was larger for HR and OHb. The strength of relationships between systemic measures and cortical oxygenation reflect this dissimilar variability.

Discussion: Autonomic system function may be compromised in PD patients compared to CON thereby influencing oxygenation indices of the prefrontal cortex of the brain. A decrease in cortical oxygenation can have a detrimental influence on the ability to maintain postural stability as well as perform complex cognitive and motor tasks. Identifying deficits in autonomic function will allow for enhanced management of potential functional deficits which may arise from autonomic insufficiency for PD patients. Clinical monitoring of frontal cortex activation and the relationship to systemic variables may contribute to better treatment and monitoring of disease progression.

References:

[1] Goldstein, D.S., L. Sewell, and Y. Sharabi, Autonomic dysfunction in PD: A window to early detection? *J Neurol Sci*, 2011. 310(1-2): p. 118-22.

[2] Hohler, A.D., et al., Differences in Motor and Cognitive Function in Patients with Parkinson's Disease with and without Orthostatic Hypotension. *International Journal of Neuroscience*. 0(ja): p. 1-13.

[3] Rao, R.P., et al., Near infrared spectroscopy: guided tilt table testing for syncope. *Pediatric Cardiology*, 2010. 31(5): p. 674-9.

Resistance training reduces force tremor in Essential Tremor patients

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Introduction. Essential tremor (ET) patients can exhibit increased postural, kinetic, and intention tremors which often result in a decreased quality of life. Given that resistance training (RT) can reduce tremor amplitude and improve upper limb fine motor control in older adults, it is surprising that few studies have explored RT as a therapy for older adults with ET. This study determined if a generalised upper-limb RT program improves manual dexterity and reduces tremor in older individuals with ET.

Methods. Ten ET patients (71 ± 5 yr) attended 3 supervised RT sessions per week for 6 weeks, where bicep curl, wrist flexion and wrist extension exercises were performed each session. Force tremor was assessed for index finger abduction force during isometric contractions at 10% and 60% MVC. Time-domain variability measures were used to examine amplitude properties of tremor, and power spectral analysis was used to examine the 0-4 Hz and 4-12 Hz oscillatory properties of force tremor. All tests were performed with the most and least affected limbs.

Results. Bicep curl, wrist flexion and wrist extension MVC significantly increased following RT. Force tremor amplitude significantly decreased during isometric finger abduction at 10% and 60% MVC for both the most affected limb (~27 %) and least affected limb (~22%). These changes were, in part, mediated by a reduction in the dominant oscillatory component that typically characterises neuromotor dysfunction associated with ET: the 5 Hz frequency component.

Discussion. A generalised RT program for the upper limb is capable of reducing abduction force tremor. While some improvements in upper limb function following RT could be attributed to general improvements in strength, changes in the 5 Hz frequency peak suggest that tremor-specific adaptations also occur. It appears that the greatest benefits following RT may be gained for the limb that has been most affected due to the disorder. Overall, it appears that RT may be a viable therapy for improving reducing force tremor in individuals with ET.

Motor control changes with pain/injury, but don't forget the muscle

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2. Uni. of Sydney, Kolling Institute of Medical Research, Sydney, Australia

3. University of New South Wales, Sydney, Australia.

Introduction: Changes in back muscle structure and behaviour are ubiquitous with back pain/injury and relevant for outcome. Although common, clear understanding of the nature, time-course, and underlying mechanisms, for muscle changes remains elusive. Particularly perplexing is the variation in structural changes of the multifidus muscle (deepest back muscles with a critical role in spine control) between studies. Although localised multifidus atrophy presents within days of injury/pain, some report no muscle changes at subacute time points, and diffuse atrophy/fatty infiltration in chronic cases. Different mechanisms may underpin structural changes at each time points. Implications for rehabilitation may differ. This study used an animal model of intervertebral disc (IVD) injury that produces back muscle changes with the aim to investigate putative cellular mechanisms to explain structural changes in muscle, adipose and connective tissues of the multifidus muscle at subacute and early-chronic time points.

Methods: Multifidus muscle was harvested from both sides of the spine at L1-2 and L3-4 in 27 male sheep at 3(n=10) or 6(n=17) months after a surgical anterolateral IVD injury at both levels. Ten control sheep had no surgery (3 months n=4; 6 months n=6). Tissue was harvested at L4 for histological analysis of cross sectional area (CSA) of muscle, adipose and connective tissue (whole muscle), plus immunohistochemistry to identify proportion and CSA of individual muscle fibre types in the deepest fascicle. Quantitative polymerase chain reaction (PCR) measured gene expression (L2 muscle tissue) of cytokines and signaling molecules for putative molecular pathways that could explain muscle atrophy, muscle fibre changes, and changes in adipose and connective tissue.

Results: Contrary to predictions, there was no multifidus muscle atrophy (whole muscle or individual fibre). Adipose and connective tissue (fibrotic proliferation) CSA increased and transition of muscle fibres from slow-to-fast type at 6, but not 3 months. Consistent with the histological data, multifidus muscle demonstrated no upregulation of pathways involved in muscle atrophy. In contrast there was significantly increased expression of genes for pro-inflammatory cytokines (TNF α and IL-1 α), molecules that signal trophic processes for adipose and connective tissue (e.g. growth factor pathway [IGF-1, PI3k, Akt1, mTOR], and potent tissue modifiers [calcineurin, PCG-1 α , and myostatin]).

Discussion This study provides cellular and whole muscle evidence that refutes the presence of multifidus muscle atrophy following IVD injury in the sub acute to early chronic period. Instead, adipose/connective tissue increased in parallel with the expression of the genes that provide putative mechanisms for multifidus structural remodeling. These data provide the foundation for a new model that defines different physiological mechanisms for acute atrophy, sub acute early chronic structural remodeling, and late atrophy.

Symposium 2: Posture, Locomotion and Exercise

Session Chair: Kylie Tucker

11:30	Anna Hudson	Activation of human inspiratory muscles in an upside-down posture
11:45	James Coxon	Effect of moderate-intensity exercise on primary motor cortex inhibition and use-dependent plasticity
12:00	David Rouffet	Does fatigue of the ankle plantar flexor muscles affect sprint cycling performance?
12:15	Jayne Garland	Distribution of <i>Triceps Surae</i> responses to postural perturbations in people post-stroke and healthy controls
12:30	Luisa Roeder	Cortical control of human gait function: Similarities and differences in corticomuscular coherence during treadmill walking and overground walking
12:45	Tjeerd Boonstra	Muscle networks in postural control

Activation of human inspiratory muscles in an upside-down posture

Anna L. Hudson¹, Fabrice Joulia^{2,3}, Annie A. Butler¹, Richard C. Fitzpatrick¹, Simon C. Gandevia¹, Jane E. Butler¹

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2. UMR MD2, Aix Marseille University & IRBA, Marseille, France

3. University of Toulon, La Garde, France

Introduction During quiet breathing, activation of obligatory inspiratory muscles differs in timing and magnitude. To test the hypothesis that this coordinated activation can be modified, we determined the effect of the upside-down posture compared with standing and lying supine.

Methods Subjects ($n = 14$) breathed through a pneumotachometer with calibrated inductance bands around the chest wall and abdomen. Surface electromyographic activity (EMG) was recorded from the scalene muscles. Crural diaphragmatic EMG and oesophageal and gastric pressures were measured in a subset of 6 subjects. Quiet breathing and standard lung function manoeuvres were performed. A control study ($n=5$) excluded electrode movement-related artefact in scalene EMG recordings.

Results The upside-down posture reduced end-expiratory lung volume. During quiet breathing, for the same inspiratory airflow and tidal volume, ribcage contribution decreased, abdominal contribution increased and transdiaphragmatic pressure swing doubled in the upside-down posture compared to standing ($p<0.05$). Despite this, crural diaphragm EMG was unchanged, whereas scalene muscle EMG was reduced by \sim half ($p<0.05$).

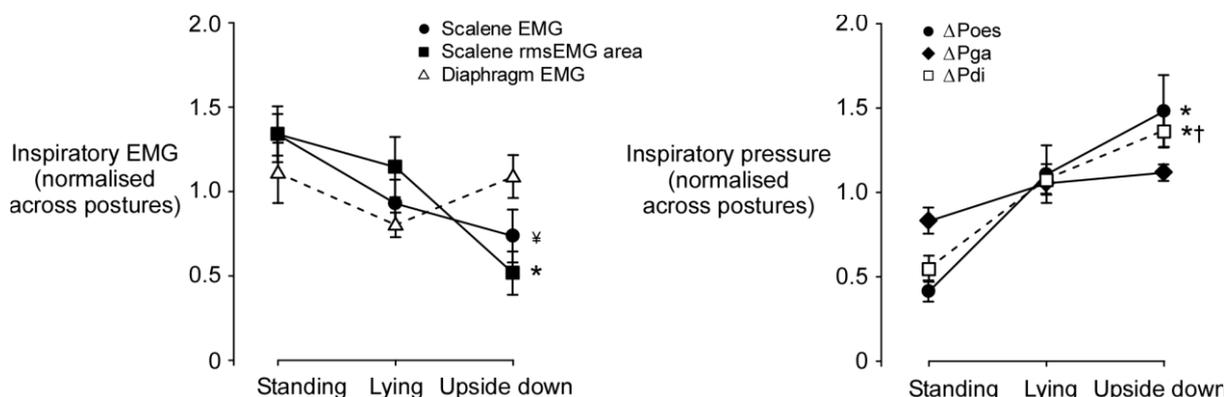


Figure shows the effect of posture on inspiratory EMG and pressures during quiet breathing.

Data are mean (SEM) for each posture, normalised to the average value across postures for each subject. Poes, Pga, Pdi: oesophageal, gastric and transdiaphragmatic pressure. * significantly different to standing, † significantly different to lying; ‡ overall significant effect of posture, but no post-hoc difference; $p < 0.05$.

Discussion Given the reversed gravitational effect on respiratory muscle mechanics, i.e. increased diaphragm 'efficiency' and decreased requirement of scalenes to elevate the ribcage, we speculate that the altered muscle activation reflects changes in the respiratory effect of the muscles.

Effect of moderate-intensity exercise on primary motor cortex inhibition and use-dependent plasticity

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Introduction Relatively little is known about the aftereffects of an acute bout of exercise on excitatory and inhibitory networks within primary motor cortex (M1). The aims of the present experiments were to 1) Investigate the effects of lower-limb aerobic exercise on gamma-aminobutyric acid (GABA) inhibition in the non-exercised M1 hand representation, and 2) Establish the effect of concurrent lower-limb aerobic exercise and directional thumb movement training on use-dependent plasticity (UDP). We hypothesised that there would be a reduction of both GABA_A and GABA_B receptor mediated inhibition following exercise, and that pairing exercise with training would enhance the expression of UDP.

Methods Participants (18 – 33 years) were assigned to one of two repeated measures cross-over experiments following an incremental intensity cardiorespiratory fitness test (VO₂ max test). In experiment 1 (n=10), transcranial magnetic stimulation (TMS) was used to assess corticomotor excitability, short (SICI) and long (LICI) intracortical inhibition, and late cortical disinhibition (LCD). In experiment 2 (n=10), corticomotor excitability and TMS evoked thumb movements were assessed. For both experiments, measures were obtained before and after 30 minutes of moderate-intensity cycling exercise (60% VO₂ max) or an equivalent period without cycling exercise. Lower-limb cycling and rest sessions were separated by 1 week and counterbalanced.

Results For experiment 1, exercise did not affect corticomotor excitability, SICI, or LCD, but was associated with reduced LICI in the first 20 minutes after exercise (time × session $F_{5,45} = 2.59$, $p = 0.04$). For experiment 2, practicing thumb movements in the opposite direction to twitches evoked by TMS caused a significant angular shift away from the baseline direction ($F_{6,54} = 6.37$, $p < 0.001$). Concurrent exercise appeared to enhance UDP in some participants, but session effects were not significant for TMS-evoked twitches into the target training zone ($F_{1,9} = 0.48$, $p = 0.28$), TMS-evoked twitch acceleration magnitude ($F_{1,9} = 1.79$, $p = 0.21$), or training agonist corticomotor excitability ($F_{1,9} = 0.64$, $p = 0.44$).

Discussion Here we present novel findings of a reduction in GABA_B receptor mediated LICI in upper-limb motor cortex following aerobic cycling exercise involving the lower-limbs. In contrast to the current literature, we did not observe a reduction in GABA_A mediated SICI in our experiment, which used interstimulus intervals of 1 ms and 2.5 ms. Pairing lower-limb exercise with thumb movement training tended to facilitate corticomotor excitability and TMS-evoked twitch acceleration magnitude, but effects were not robust across the sample. Insufficient power, or variation in factors known to influence neuroplasticity induction may have influenced the result.

Does fatigue of the ankle plantar flexor muscles affect sprint cycling performance?

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Introduction: Substantial decreases in the net power produced at the ankle joint during plantar flexion have been associated with large reductions in crank power during the course of a maximal cycling exercise. However, it remains unclear if fatigue of the ankle plantar flexor (APF) muscles causes this reduction in ankle joint power and subsequently the decrease in crank power production during a maximal cycling exercise. The aims of this study were to investigate 1) if a 30-s maximal cycling exercise causes fatigue in the APFs and 2) if pre-fatiguing the APFs affects ankle joint power and crank power production during a 30-s maximal cycling exercise.

Methods: Ten physically-active participants performed a 30-s maximal cycling exercise under two randomized conditions: 1) control condition (CTL) and 2) after pre-fatiguing the APF muscles (APF-). In the APF- condition, a 40% reduction in APF force ($isoF_{APF}$) was induced using a series of 3-s maximal isometric contractions interspersed with 6s recovery. Immediately before and after the maximal cycling exercise, neuromuscular testing (NMT) of the APFs was completed to measure $isoF_{APF}$, EMG ($isoEMG_{SOL/GAS}$) and resting maximal M-waves ($M_{SOL/GAS}$). During the 30-s cycling exercise, average values of the EMG activity of APF muscles ($cycEMG_{SOL/GAS}$), joint power produced at the ankle during plantar flexion ($cycP_{APF}$) and crank power ($cycP_{crank}$) were calculated for five 6-s intervals. Two-way ANOVAs with repeated measures were used to evaluate the effects of condition and time on all measurements.

Results: Reductions in $isoF_{APF}$ ($-39\pm 10\%$), $isoEMG_{SOL}$ ($-46\pm 14\%$), $isoEMG_{GAS}$ ($-40\pm 16\%$), M_{SOL} ($-19\pm 15\%$) and M_{GAS} ($-12\pm 15\%$) were induced before the start of the cycling exercise in the APF- condition. For both conditions, $cycEMG_{SOL}$ ($29\pm 7\%$ vs. $16\pm 5\%$), $cycEMG_{GAS}$ ($37\pm 9\%$ vs. $28\pm 8\%$), $cycP_{APF}$ ($128\pm 49W$ vs. $37\pm 14W$) and $cycP_{crank}$ ($467\pm 132W$ vs. $231\pm 52W$) decreased between intervals 1 and 5 of the 30-s cycling exercise (all p 's <0.05). Differences between the two conditions were larger during interval 1 compared to interval 5 for all variables: $cycEMG_{SOL}$ ($-9\pm 5\%$ vs. $-3\pm 2\%$), $cycEMG_{GAS}$ ($-9\pm 7\%$ vs. $-5\pm 6\%$), $cycP_{APF}$ ($-14\pm 20W$ vs. $-2\pm 8W$) and $cycP_{crank}$ ($-29\pm 28W$ vs. $-3\pm 36W$). After the cycling exercise, $isoF_{APF}$ ($-13\pm 8\%$), $isoEMG_{SOL}$ ($-34\pm 16\%$), $isoEMG_{GAS}$ ($-14\pm 18\%$) and M_{SOL} ($-9\pm 17\%$) were lower during the APF- condition, whereas M_{GAS} ($-1\pm 21\%$) was comparable to CTL condition.

Discussion: In the CTL condition, no fatigue could be detected in the APF muscles after completion of a 30-s maximal cycling exercise. Pre-fatiguing the APFs caused reductions in APF power, APF EMG and crank power during the early part of the 30-s maximal cycling exercise. Participants progressively recovered from the pronounced fatigue in the APF muscles through the course of the the 30-s maximal cycling exercise. In conclusion, our results show that high levels of fatigue in the APF muscles can affect power production during sprint cycling exercises, however sprint cycling exercises do not seem to induce levels of fatigue in the APF muscles that can reduce sprint cycling performance.

Distribution of Triceps Surae Responses to Postural Perturbations in People Post-Stroke and Healthy Controls

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Introduction. Traditionally, electromyographic (EMG) activity has been measured with bipolar surface recordings or fine wire intramuscular recordings, both of which have a relatively restricted pick-up volume. We have used high-density surface EMG (HDsEMG) grid electrodes to sample EMG activity across the triceps surae muscles in healthy controls and in people with chronic stroke. Given the sarcopenia and motor control impairments resulting from stroke, we sought to explore if these impairments influenced the distribution of the EMG response within the ankle plantarflexor muscles to standing external perturbations and the reproducibility of the EMG responses on different days.

Methods. Participants performed the same experiment on two occasions, one week apart. Participants stood with their feet shoulder-width apart, with each foot on a separate force platform. A belt, secured around the pelvis, was attached to a horizontal cable in front of the participant. Anteriorly-directed external loads of 2% body mass (BM) were applied via the cable-pulley system by dropping loads into a basket from a height of 40 cm. The load was maintained in the basket for 10 s and then removed. This was repeated ten times, with 15-30 s (random timing) between perturbations.

HDsEMG recordings from the soleus (SOL) (24 electrode grid, 2 cm interelectrode distance), medial (MG) and lateral gastrocnemius (LG) (20 electrode grids each, 1.5 cm interelectrode distance) were collected bilaterally. HDsEMG signals were analyzed in bipolar configurations resulting in 18 EMG signals from SOL muscle and 16 from each of MG and LG muscles. The EMG onset time was calculated from the time the load hit the basket to when the EMG response exceeded 20% of the peak envelope. The EMG area and peak slope of each bipolar configuration was measured for 50 ms after the EMG onset time to capture the initial response to the perturbation.

The distribution of the EMG recordings across the bipolar configurations within a muscle was quantified using the interquartile range (IQR). The between-day reproducibility of median of the EMG response was determined using intraclass correlation coefficients (ICC).

Results. The median EMG onset time was significantly larger in paretic (117 ms) than non-paretic (88 ms) and control (95 ms) legs, with no significant difference in the IQR across groups or muscles. Similarly, the paretic EMG slope and area were also smaller than healthy controls, with comparable IQRs. The median values for EMG onset time were highly reproducible between days with ICCs over 0.90 in all groups, whereas the paretic EMG slope and area values were less reproducible between days (ICCs of 0.60 - 0.70) than controls (ICCs of 0.7 - 0.8).

Discussion. Although expected differences were found in the EMG responses to standing perturbation after stroke (delayed onset times, lower magnitudes), the novel finding was the similarity in the distribution of EMG activity within and across muscles between stroke and healthy controls. This suggests that a certain level of homogeneity of response within the muscle is retained after stroke. Finally the onset timing is highly reproducible on different days in chronic stroke, suggesting that this parameter may be more useful than measures of EMG magnitude in determining change with treatment.

Cortical control of human gait function: Similarities and differences in corticomuscular coherence during treadmill walking and overground walking

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Introduction: There is increasing evidence that the cortex is involved in human locomotor control, as revealed by corticomuscular coherence during treadmill walking. Although treadmill and overground walking have similar temporospatial gait patterns in healthy people, differences in kinetic parameters and muscle activation patterns have been observed. In the present study we compare corticomuscular coherence between EEG and EMG from active leg muscles during treadmill walking and natural overground walking to investigate similarities and differences of the transmission of motor cortical activity to the muscle between the two gait modalities.

Methods: Six healthy human subjects (mean age 30.1 ± 7.7 years; 1 woman) performed overground walking and treadmill walking at a comfortable, self-selected pace (3.5 – 5 km/h) while EEG (sampled at 2kHz, filtered 1-500 Hz) and EMG (sampled at 2kHz, filtered 1-1000Hz) were recorded. Spectral analysis was performed according to the theoretical framework described by Halliday et al. (1995) and Rosenberg et al. (1989) and calculated using the publicly available MATLAB toolbox NeuroSpec 2.0. Pooled coherence was computed between the Cz EEG electrode and the tibialis anterior (TA) muscle of the right leg. Time-dependent coherence was calculated relative to the heel strike of the right foot.

Results: During treadmill and overground walking, corticomuscular coherence was significant at 12-25 Hz (alpha, beta) for offsets between -450 ms prior to 50 ms post heel strike. Significant coherence was also observed at lower frequency bands from 2-7 Hz (theta) from -700 ms prior to 50 ms post heel strike during treadmill walking and -800 ms to -300 ms prior to heel strike during overground walking. When comparing both gait modalities, coherence was significantly higher during treadmill walking in theta, alpha and beta frequencies at most times of the gait cycle (-800 ms to -425 ms prior, -275 ms prior to 25 ms post, 125 ms to 200ms post heel strike, $p < 0.01$).

Discussion: We found similar patterns of significant corticomuscular coherence in beta frequency bands during treadmill walking and overground walking. This suggests that rhythmic cortical activity is transmitted via the corticospinal tract to the active leg muscles in similar manner during both gait modalities. In addition to beta-band coherence, we also observed significant EEG-EMG coherence in frequency bands below 10 Hz, which have not been reported previously. However, we found different levels of corticomuscular coherence during treadmill and overground gait. We interpret the higher coherence levels during treadmill walking as increased cortical control, which may indicate that normal, steady-state overground walking requires less conscious attention than artificially induced treadmill gait. From a clinical perspective, this has important implications for gait function recovery training in individuals with injuries or disease of the central nervous system.

Muscle networks in postural control

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Introduction

Understanding the mechanisms that reduce the many degrees of freedom in the musculoskeletal system remains an outstanding challenge. Muscle synergies reduce the dimensionality but how muscle synergies are implemented in the central nervous system is not yet known. We propose a novel approach to derive muscle networks from EMG recordings and use network theory to assess the neural circuitry involved in the formation of muscle synergies.

Methods

We acquired EMG activity from postural muscles while subjects (n=18) were standing in different conditions. Intermuscular coherence and partial directed coherence was estimated between all muscle combinations. Non-negative matrix factorization (NMF) was used to decompose the coherence spectra into distinct frequency components and their corresponding coupling strength. The coupling strengths yield the weighted connectivity matrix that can be assessed using network analysis.

Results

Muscle networks were observed at multiple frequency bands, each of which showed a distinct topology. At the lower frequencies (<5 Hz) muscle networks showed strong inter-limb connections, whereas networks at higher frequencies (>15 Hz) mainly revealed intra-limb connections. We observed significant differences between frequencies in measures of network topology, namely the clustering coefficient, global efficiency and betweenness-centrality. In addition, the clustering coefficient and global efficiency were significantly higher when standing at height.

Discussion

These findings demonstrate that muscle networks can be used to quantify changes in motor coordination involving multiple postural muscles. The presence of disparate muscle networks across frequencies suggests that the neuromuscular system is organized into a multiplex network allowing for parallel and hierarchical control structures. Different frequencies likely reflect different pathways innervating spinal motor unit pools: higher frequencies are generated by local circuitry and lower frequencies by long-range connections. The robust patterns of partial directed coherence indicate the involvement of spinal networks in the formation of muscle synergies.

Symposium 3: Sensorimotor Adaptation

Session Chair: Simon Gandevia

2:30	Sauro Salomoni	Local and remote pain can compromise the ability to learn a new locomotor task
2:45	Lilian Chye	Ballistic training induces systematic aiming bias in the opposite, untrained limb that is defined according to multiple spatial frames of reference
3:00	James Nuzzo	Ballistic and slow ramp isometric training of the elbow flexors increase responses to stimulation of corticospinal axons
3:15	Julianne Baarbé	Low Grade Neck Pain Interferes with the Ability to Perform a Mental Rotation Task
3:30	Li-Ann Leow	Anodal motor cortex stimulation paired with movement repetition increases anterograde interference but not savings
3:45	Tino Stöckel	Insights into the mechanisms underlying cross-limb transfer following unilateral ballistic motor learning

Local and remote pain can compromise the ability to learn a new locomotor task

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Introduction. It is well understood that pain affects movement control at multiple levels of the motor system. Moreover, recent studies provide evidence that acute pain may inhibit cortical/spinal plasticity associated with motor learning. For example, it has been proposed that exposure to uncontrollable nociceptive stimulation inhibits adaptive spinal learning in spinalized rats. In humans, experimental skin pain may compromise long-term retention of a newly learnt locomotor task. The aim of this study was to assess the effects of pain on motor learning when pain is induced to a body segment that is directly involved (Local) or not involved (Remote) in the new motor task.

Methods. Forty-two healthy participants walked on a treadmill on two sessions over consecutive days. During each session, participants walked for 5 minutes under three conditions: before (Baseline), during (Perturbation), and after (Recovery) a perturbation was applied. During Perturbation, a strong elastic tube pulled the foot forward and upward, and participants were instructed to "overcome the perturbation and walk as normally as possible". On day 1, the task was performed either under pain-free condition (Control group, n=14), or after skin pain was induced via topical application of capsaicin cream (1%) to the posterior aspect of the thigh, ipsilateral to the perturbation (Local group, n=14) or to the contralateral wrist (Remote group, n=14). The same task was repeated on day 2 in the absence of pain. Task performance was measured as peak foot velocity during swing phase. Performance during early (initial 5 strides) and late (last 100 strides) Perturbation was expressed as % of late Baseline and used for further analysis. A three-way ANOVA (Group: Control, Local, Remote; Day: 1, 2; Epoch: Early, Late) was performed to assess both within-session adaptation and between-session retention of the task.

Results. There was a significant Group×Day×Epoch interaction ($p<0.001$). All groups reduced peak foot velocity error with training on Day1 (Early: 43% vs. Late: 19%, $p<0.001$), and showed retention of the motor task (Early Day1: 43% vs. Early Day2: 18%, $p<0.001$). The initial performance of the Local group was worse than Control and Remote (Early Day1 Local: 54%; Control: 37%; Remote: 37%). The Control group performed better than the Remote group at the end of Day2 (12% vs. 17%, $p=0.05$), with no difference compared with the Local group ($p=0.12$). The Control group was the only to show a non-significant tendency for improved performance on Day2 (Early: 17% vs. Late: 12%, $p=0.06$), with a non-significant tendency for smaller peak foot velocity error than in Day1 (Late Day1: 17% vs. Late Day2: 12%, $p=0.06$).

Discussion. Pain caused an initial deficit in the performance of the Local group. However, this deficit was overcome by Late Day1, presumably because lack of adaptation would increase the risk of tripping and falling. Although adaptation on Day 1 was not significantly affected by pain, only the Control group showed a trend for improved performance on Day 2, suggesting that training with local or remote pain on Day1 may have hindered further improvement of task performance under pain-free conditions on Day2. These results are in line with animal studies, which report that pain induces motor learning deficits beyond the duration of pain.

Ballistic training induces systematic aiming bias in the opposite, untrained limb that is defined according to multiple spatial frames of reference

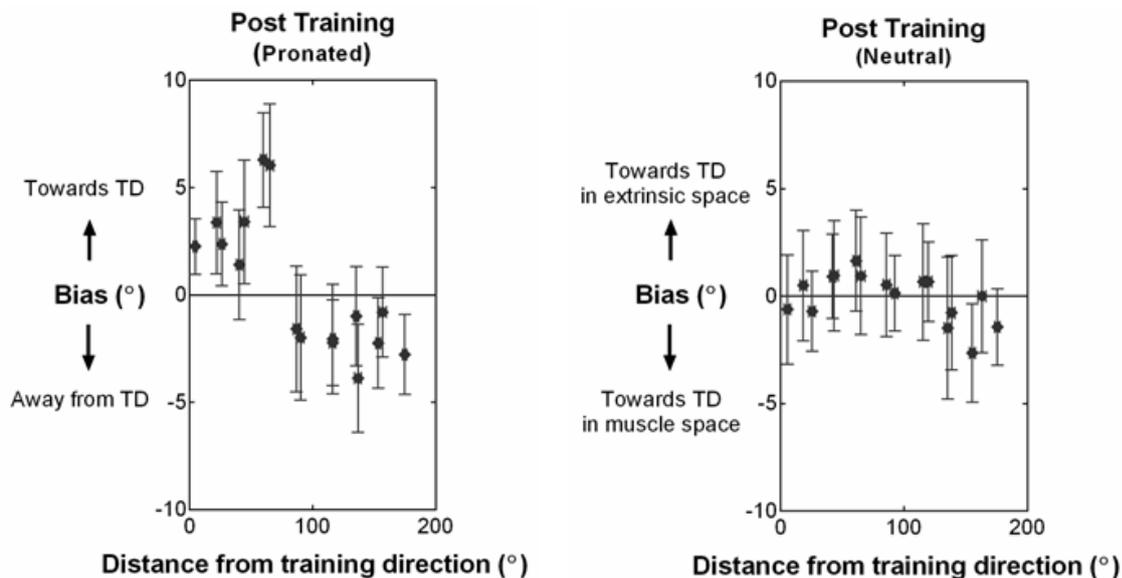
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Use-dependent learning was previously reported to generalise according to extrinsic coordinates when posture changes were used to dissociate reference frames within the active limb, however it is unclear whether this form of learning generalises to the untrained limb. Here we assessed whether use-dependent bias in aiming performance occurred in the opposite, untrained limb under postural manipulations that varied whether or not the training direction (TD) was aligned for the two limbs according to extrinsic, muscle-based, and midline reference frames.

Participants (n=59) were randomly assigned to train with a pronated or neutral wrist position. The training directions (TD) defined according to extrinsic and midline-referenced coordinates are congruent for extension and flexion movements performed with both hands in the pronated posture, but conflicting in the neutral position. After participants performed ballistic training to a single target (flexion or extension) with the left wrist, aiming bias was probed for the right wrist via an aiming task that required weak forces to acquire 16 radial targets.



The figure shows the aiming bias in pronated and neutral positions after ballistic training in the untrained limb.

Aiming bias showed a linear trend ($F_{(1, 31)} = 17.7$, $p < 0.001$, $\eta_p^2 = 0.36$) when both limbs were oriented in the pronated position. Positive bias in pronation is consistent with bias toward the TD defined according both to extrinsic and muscle space, whereas negative bias near 180° is consistent with bias towards the training axis. The lack of significant bias observed for the neutral position might be due to opposing effects of extrinsic versus muscle (and midline) representations of the trained movement ($p > 0.05$). The data suggest that use-dependent learning that underlies aiming biases in the untrained limb after contralateral ballistic training is represented according to a combination of coordinate systems.

Ballistic and Slow Ramp Isometric Training of the Elbow Flexors Increase Responses to Stimulation of Corticospinal Axons

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Introduction: Spinal cord changes from an acute bout of strength training have not been well-characterized. Also, adaptations may depend on the type of strength training. The purpose of the current study was to determine if one session of strength training of the elbow flexors leads to changes in the corticospinal pathway in the spinal cord and if the type of training is important.

Methods: Healthy subjects ($n = 13$) completed ballistic isometric training (12 sets of 8 contractions at ~75% peak force) of the elbow flexors in one session, and slow-ramp training in another. Transcranial magnetic stimulation over contralateral motor cortex elicited motor evoked potentials (MEPs); electrical stimulation of corticospinal tract axons at the cervicomedullary junction elicited cervicomedullary motor evoked potentials (CMEPs); and electrical stimulation of the brachial plexus elicited maximal compound muscle action potentials (M_{\max}) in resting biceps brachii. MEP, CMEP, and M_{\max} twitch forces were also obtained. MEPs and CMEPs were normalized to M_{\max} . Two-way repeated measures ANOVA (factors: training type and time) assessed changes in the variables.

Results: For MEPs, CMEPs, MEP twitch forces, and CMEP twitch forces, there were significant main effects for time (all $p < 0.001$), as responses increased after training. Notably, CMEPs and CMEP twitch forces remained elevated for 25 minutes after training. For M_{\max} and M_{\max} twitch forces, there were significant main effects for time ($p < 0.001$), as responses decreased after training. There were no main effects of training type or training type \times time interactions.

Discussion: The results demonstrate that one session of strength training of the elbow flexors leads to increased responsiveness of the corticospinal pathway. The increased CMEPs and CMEP twitch forces indicate spinal level changes that are preferential for the training direction and suggest an increase in gain of corticospinal input to the motoneurons of the trained muscles. A coexisting increase in motor cortical excitability appears likely. However, the type of isometric strength training is not important.

Low Grade Neck Pain Interferes with the Ability to Perform a Mental Rotation Task

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Introduction: The concept of an altered body schema in individuals with chronic pain has become a recent area of interest, with the altered schema extending to peripersonal space. Mental rotation of an object, is a complex task requiring prediction and cerebellar involvement and one past study showed that it improved with single session of cervical manipulation¹. Neck pain has been shown to impact upper limb proprioception² and recent neurophysiological studies suggest that individuals with neck pain (NP) may have altered cerebellar processing³ which coincided with altered motor performance. It is therefore likely that neck pain may interfere with the ability to perform a mental rotation task. The purpose of this longitudinal study was to compare the mental rotation ability of those with NP to healthy controls, both at baseline and again after four weeks. We hypothesized that the healthy group would improve their ability to perform mental rotation over time, whereas those with neck pain would show less improvement.

Methods: Twenty six volunteers (13 NP and 13 controls) recruited from a university student population participated in this longitudinal study. NP participants had scores of mild to moderate on the Chronic Pain Grade Scale and controls had minimal or no pain. Participants attended two sessions, at baseline and four weeks later. For the mental rotation task, participants were presented with an object (letter 'R') on a computer screen and they had to indicate the object's orientation (they pressed 'N' for normal, 'B' for backwards). The letter 'R' was presented randomly in either backwards or normal parity, at various orientations (0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°). E-Prime™ software was used to measure reaction time with the letter presented at these random orientations. Each orientation time was presented 5 times and the average reaction time to all letter presentation was calculated for each participant both at baseline and when they repeated the task four weeks later.

Results: Healthy participants had mean baseline reaction times (\pm standard deviations) of 981.2 ± 208.4 ms, which improved significantly ($P=0.008$) to 771.5 ± 285.6 ms at four weeks, an average improvement of 209.8 ± 236.8 ms. The NP group had baseline times of 1220.9 ± 294.5 ms vs 1115.8 ± 220.8 ms at four weeks, and average improvement 105 ± 263.6 ms which was not significant. The baseline reaction time was significantly different between groups ($p=0.025$).

Discussion: Healthy participants improved significantly on the mental rotation task while the neck pain group did not. The NP group also had faster baseline reaction times. These results suggest that NP may impair the ability to perform a complex mental rotation task involving cerebellar connections, possibly due to an altered body schema.

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Anodal motor cortex stimulation paired with movement repetition increases anterograde interference but not savings

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Introduction: Retention of motor adaptation is evident in savings, where initial learning improves subsequent learning, and anterograde interference, where initial learning impairs subsequent learning. Previously, we showed that savings and anterograde interference have different training requirements, leading to the suggestion that savings and anterograde interference do not result from equal contributions of the same mechanisms (Leow et al., 2013). We proposed that use-dependent movement biases induced by movement repetition contribute to anterograde interference, but not to savings. Here, we test this proposal by limiting or extending movement repetition as we augmented use-dependent plasticity via anodal motor cortex (M1) transcranial direct current stimulation (tDCS). Anodal M1 tDCS is known to increase use-dependent plasticity when applied during movement repetition (Galea and Celnik, 2009).

Methods: Participants first adapted to a counterclockwise rotation of visual feedback imposed either abruptly (extended repetition) or gradually (limited repetition) in a first block (A1), during which either sham or anodal tDCS (2 mA) was applied over M1. Anterograde interference was then assessed in a second block (B) with a clockwise rotation, and savings in a third block (A2) with a counterclockwise rotation.

Results & Discussion: Anodal M1 tDCS elicited more anterograde interference than sham stimulation with extended but not with limited movement repetition. Conversely, anodal M1 tDCS did not affect savings with either limited or extended repetition of the adapted movement. Crucially, the effect of anodal M1 tDCS on anterograde interference did not require large errors evoked by an abrupt perturbation schedule. By systematically manipulating target locations during a gradually induced perturbation, we enforced extended movement repetition within the context of implicit adaptation in response to small errors. Similar to our results where anodal M1 tDCS increased anterograde interference but not savings when movement repetition was enforced by an abrupt perturbation schedule, anodal M1 tDCS increased anterograde interference but not savings when movement repetition was enforced within a gradual perturbation schedule. These findings demonstrate that **use-dependent plasticity contributes to anterograde interference, but not to savings.**

Insights into the mechanisms underlying cross-limb transfer following unilateral ballistic motor learning

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Introduction: Cross-limb transfer is the performance benefit conferred in the untrained limb after practice of a task with the contralateral limb. While the existence of cross-limb adaptations has been confirmed in many phenomenological and behavioural studies, the mediating mechanisms remain poorly understood. The aim of the present study is to understand the neural processes underlying cross-limb transfer of motor skill by means of non-invasive brain stimulation. Specifically, we investigated the effects of intermittent theta-burst stimulation (iTBS), a high frequency transcranial magnetic stimulation (TMS) protocol that has been shown to enhance corticospinal excitability (CSE), on prior and subsequent motor learning and accompanying cross-limb transfer effects.

Methods: Thirty-six healthy participants practiced a ballistic motor task with their dominant right index finger (150 trials), followed by iTBS applied to either the contralateral, trained (left) primary motor cortex (cM1 group), the ipsilateral, untrained (right) motor cortex (iM1 group), or the vertex (SHAM group), followed by a further 150 training trials. Performance (peak acceleration of the index finger) and CSE (MEP amplitudes of the FDI muscle evoked by single pulse TMS) were assessed before motor learning, pre- and post-iTBS, and following the second training session.

Results: For all groups, motor training significantly increased performance and CSE of the trained hand, and performance, but not CSE, of the untrained hand. Performance gains in the untrained hand were predicted by training-induced performance and CSE gains in the trained hand. Following iTBS, performance and CSE were significantly reduced in the cM1 group's trained hand by 37% and 27% respectively, while the untrained hand remained unaffected. In the iM1 group, participants' performance and CSE of the untrained hand increased by 41% and 39% respectively without affecting the trained hand. No significant effects of iTBS were observed in the SHAM group.

Discussion: First, these results suggest that movement information stored in the untrained hemisphere during motor learning, as opposed to information stored in the trained hemisphere, is subsequently retrieved to drive cross-limb adaptation. Second, motor learning and accompanying cross-limb transfer appear to represent distinct adaptation processes. That is, cM1 iTBS *degraded* motor learning gains in the trained hand a finding which is consistent with homeostatic plasticity whereby prior motor learning (a LTP process) reversed the expected LTP-like effects of iTBS in this hemisphere. In contrast, iM1 iTBS *facilitated* untrained hand performance (indicative of a LTP-like effect), despite the fact that this hand had also significantly benefited from unilateral motor training; this suggests that adaptations due to cross-limb transfer interact different with iTBS than do actual use-dependent gains. The findings have implications for clinical and rehabilitation settings.

Symposium 4: Young Investigator Session

Session Chair: Tim Carroll

9:30	Victor Selvanayagam	Interaction between error-based and use-dependent learning
9:45	Jessica D'Amico	Activation of 5HT1A receptors inhibits motoneurone excitability in humans
10:00	Eugene Poh	Distinct coordinate systems for adaptations of movement direction and extent
10:15	David Kennedy	Exercise performance of quadriceps is impaired by fatigue-related muscle nociceptive feedback from antagonist but not homonymous contralateral muscles
10:30	Paola Reissig	The role of mirror visual feedback and mirror muscle activity on cross-limb adaptations in young and older adults
10:45	Matthew Jones	Isometric exercise increases pressure pain threshold but has no effect on pain-related somatosensory evoked potentials in healthy individuals

Interaction between error-based and use-dependent learning

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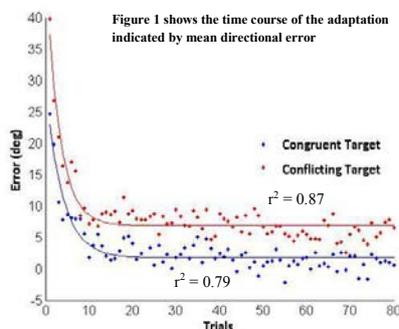
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Introduction Repeated movements to a single target induce biases to subsequent movements towards the direction of the repeated action. This use-dependent effect is thought to be at least partially due to Hebbian synaptic plasticity in the primary motor cortex^{1,3}. However, the interaction between use-dependent learning and other forms of motor learning, such as error-based and reinforcement learning, has received little attention. Here we test whether use-dependent learning affects subsequent adaptation to a visuomotor rotation task. Since a previous report indicates that repetition of a low force movement has no effect on the rate of adaptation², we used here a high-force training protocol that induces robust bias effects, and probed effects on visuomotor adaptation for targets that coincided with peak bias.

Methods Participants (n=20) performed five sets of 8 maximal force with their right wrist toward a single target (either 45, 135, 225, or 315 deg; counterbalanced across subjects). Before and after training, they performed an isometric aiming task toward two targets separated by an equal angle (67.5 deg in either direction) from the high force ballistic training target. Following training, we applied either a 30° clock-wise (Group CW; n = 12) or counter clock-wise (Group CCW; n= 8) rotation. Since use-dependent learning should bias movements towards the correct solution to the visuomotor rotation for one target and away from the correct solution for the other target, we expect improved visuomotor adaptation for the first target as compared to the other. Aiming errors were compared between targets for which use-dependent bias was congruent with, versus conflicting with, the correct visuomotor solution, and plots of error size versus trial number were fitted using a single exponential function. Students' t-test were used to compare the average rate of adaptation, asymptote and aiming error from the first 10 learning trials, as a measurement of initial performance, and the last 10 trials as measurement of final performance.



Results Motor adaptation was greater for the target for which use-dependent learning bias was congruent with the correct visuomotor solution as illustrated in Figure 1. There was also a significant difference in asymptote ($p < 0.01$) and both initial ($p < 0.01$) and final performance ($p < 0.01$) between the two targets.

Discussion Our results show that high force contractions produce a use-dependent learning effect that can either increase or decrease the completeness of visuomotor adaptation, depending upon whether the required visuomotor solution lies close or further away from the direction of repeated action. We suspect that the interaction occurred in the primary motor cortex. Future work could assess the role of high drive and aim to identify the neural site of interaction.

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Activation of 5HT1A Receptors Inhibits Motoneurone Excitability in Humans

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Introduction: Intense descending drive in the adult turtle spinal cord results in serotonin spillover to the axon hillock of the motoneurons. This activates inhibitory 5HT1A receptors and hence, inhibits action potential generation¹. This mechanism has been proposed to contribute to central fatigue. In this study we examined whether activation of 5HT1A receptors can inhibit motoneurone excitability in humans by determining the effects of a 5HT1A receptor partial agonist, buspirone, on F-waves and cervicomedullary motor evoked potentials (CMEPs).

Methods: Participants (n=10) attended two experimental sessions where either placebo or a 20mg dose of buspirone was administered orally. Investigators and participants were blinded and the order of drug delivery was randomized. The ulnar nerve was stimulated supramaximally to evoke F-waves in abductor digiti minimi (ADM). Additionally, electrical cervicomedullary stimulation elicited CMEPs of ~10-20% of the maximal M-wave (Mmax) in biceps brachii and Mmax was elicited by brachial plexus stimulation. Measurement blocks consisted of 60 F-waves, 5 CMEPs and 2 biceps Mmax. These measurements were repeated 3 times at 10-min intervals prior to pill intake, and again every 10 min from 25 to 105 min after pill intake. F-wave and CMEP areas were normalized to Mmax and averaged for each measurement block. F-wave persistence was also measured. Post-drug measurements were normalized to average baseline values. For each measure, the peak decrease after buspirone was compared to that after placebo using a paired t-test.

Results: The peak decrease in ADM F-waves was significantly different between treatment conditions with F-wave area decreasing by 18±15% after placebo and 52±17% after buspirone (mean±SD, p<0.001). ADM F-wave persistence also decreased significantly more after buspirone intake (placebo: -5±7% vs. buspirone: -27±19%, p<0.001). Peak decreases in biceps CMEPs following buspirone were also greater than those after the placebo (placebo: -35±30% vs. buspirone: -70±23%, p=0.03).

Conclusion: Activation of 5HT1A receptors with buspirone decreases motoneurone excitability as measured by F-waves and CMEPs. Moreover, F-waves are decreased immediately following sustained maximal contractions in the leg and hand². Taken together these results suggest that activation of 5HT1A receptors through serotonin spillover during voluntary contractions is a plausible contributor to central fatigue.

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Distinct coordinate systems for adaptations of movement direction and extent

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Introduction Learned compensations to perturbed visual feedback of movement extent and direction generalize differently to unpractised movement directions, which suggests different underlying neural mechanisms. Generalization of visuomotor gains can be explained by linear combinations of single-gains in "mixture-of-experts" models, whereas the bell-shaped generalization of visuomotor rotation can be captured by basis function models with directionally tuned neurons. Here we investigated whether gain and rotation adaptations are represented in different coordinate systems.

Methods Subjects performed a force aiming task with the wrist, and learned a pattern of gains or rotations comprising of opposite orientations for different force directions. Generalization was tested with the forearm in a different pronation-supination orientation, which allowed the joint-based coordinates of the perturbation to be set either in direct conflict with, or in accordance with the extrinsic coordinates. We first examined adaptation to visuomotor gain (1.4 and 0.6 times baseline force) or rotation ($\pm 30^\circ$) with the right forearm in a pronated position, and generalization was assessed with the forearm rotated by 90° clockwise (i.e. in a neutral position). Due to the pattern of perturbation used (i.e. opposite for orientations separated by 90 degrees), this posture shift caused the orientation of the perturbation to conflict in extrinsic versus intrinsic coordinates. In a second experiment, we examined adaptation to the same patterns of visuomotor gains and rotations used in experiment 1, but the forearm orientation was rotated 180° from supination to pronation such that the perturbation directions were aligned in both intrinsic and extrinsic coordinates.

Results When the 90° change in forearm orientation caused the imposed perturbations to conflict in extrinsic and joint-based coordinates, rotation generalization occurred in extrinsic coordinates but with reduced magnitude ($-27.3 \pm 6\%$). In contrast, gain generalization was both reduced ($-40.4 \pm 7\%$) and shifted in phase toward the joint-based coordinates by $27.4 \pm 8^\circ$. In comparison, when the forearm was rotated by 180° such that all imposed perturbations aligned in both joint-based and extrinsic coordinates in both postures, rotation generalization was further reduced ($-55.7 \pm 6\%$), whereas there was neither a significant reduction nor phase shift in the pattern of gain generalization.

Discussion These results show that rotation generalization was expressed in extrinsic coordinates, and that generalization magnitude was modulated by posture. In contrast, gain generalization was determined by the target direction defined according to an integrated combination of extrinsic and joint-based coordinates, and was not reduced substantially by posture changes alone. The dissociations between the patterns of gain and rotation generalization demonstrate that adaptations of movement direction and extent are represented according to distinct coordinate systems.

Exercise performance of quadriceps is impaired by fatigue-related muscle nociceptive feedback from antagonist but not homonymous contralateral muscles

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AIM: During fatiguing exercise of the upper limb, group III/IV muscle afferent feedback reduces voluntary drive and force of fatigued and unfatigued muscles of the same limb (1, 2, 3). However, the extent to which these afferents affect the lower limb is unknown. Our aim was to investigate the effects of fatigue-related group III/IV muscle afferent feedback from ipsilateral and contralateral fatigued muscles of the thigh.

METHODS: In two experiments we measured right knee extension and flexion forces and contralateral (left) knee extension force. Paired electrical stimuli were delivered to the femoral nerve during and after maximal knee extension efforts to evoke superimposed and resting twitches from quadriceps and provide a measure of voluntary activation. Experiment 1: On two days, subjects (n=8) performed brief maximal voluntary contractions (MVCs) of the right quadriceps before and after a 2-min MVC of the right hamstrings. Experiment 2: The experiment was similar, except subjects performed 2-min MVCs of the contralateral (left) quadriceps prior to brief right quadriceps MVCs. For each experiment, on one day a sphygmomanometer cuff occluded circulation of the fatigued muscles after the 2-min MVC, and so maintained group III/IV muscle afferent feedback.

RESULTS: *Experiment 1:* After the 2-min *hamstring* MVC, both mean *quadriceps* force ($67.6 \pm 22.8\%$ v. $95.7 \pm 9.8\%$ peak MVC; $P < 0.05$) and voluntary activation ($59.0 \pm 20.6\%$ v. $79.1 \pm 8.9\%$; $P < 0.01$) were lower with than without circulatory occlusion. *Experiment 2:* After the *contralateral* (left) MVC, both mean *quadriceps* force ($102.4 \pm 9.6\%$ peak MVC v. $99.0 \pm 7.5\%$ peak MVC; $P = 0.48$) and voluntary activation ($92.1 \pm 5.6\%$ v. $92.9 \pm 4.1\%$; $P = 0.65$) of the right leg were no different with or without circulatory occlusion.

CONCLUSION: Group III/IV muscle afferent feedback from fatigued hamstrings acts to reduce voluntary activation and force of non-fatigued quadriceps in the same limb. Although these afferents can affect the performance of muscles of the same limb, our findings suggest that there is no contralateral cross-over effect on performance of unfatigued muscles mediated by group III/IV muscle afferents of the thigh.

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The role of mirror visual feedback and mirror muscle activity on cross-limb adaptations in young and older adults.

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Cross-limb transfer (CLT) describes bilateral performance gains as a consequence of unilateral motor practice. CLT may be reduced, or absent, in older adults, possibly due to age-related structural and functional brain changes. Based on research that has suggested increases in CLT due to the provision of mirror visual feedback during task execution in young adults, our study aimed to investigate whether augmented visual feedback can facilitate CLT in older adults, who are more reliant on visual feedback for accurate motor performance. Additionally we aimed to identify possible predictors for CLT in younger and older adults.

Participants ($N = 53$) engaged in a short-term training regime (300 movements) involving a ballistic finger task using their dominant hand, while being provided with either visual feedback of their active limb, or a mirror reflection of their active limb (giving the impression the quiescent limb was performing the task). We assessed bilateral performance and corticospinal excitability (using TMS) before, during and following unilateral training, and assessed bilateral muscle activity via EMG.

Training resulted in significant bilateral performance gains that neither differed as a result of age nor visual feedback (all $ps > 0.1$). Training elicited bilateral increases in corticospinal excitability ($p = 0.049$). For younger adults, CLT was significantly predicted by performance gains in the trained hand ($\beta = 0.470$), whereas for older adults CLT was significantly predicted by mirror activity in the untrained hand during training ($\beta = 0.604$).

The present study suggests that older adults are capable of exhibiting CLT to a similar degree to younger adults. The prominent role of mirror activity in the untrained hand for CLT in older adults further suggests bilateral cortical activity during unilateral motor tasks to be a compensatory mechanism. In this particular task, augmented visual feedback did not appear to influence the extent of CLT.

Isometric exercise increases pressure pain threshold but has no effect on pain-related somatosensory evoked potentials in healthy individuals

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INTRODUCTION: The effects of acute exercise on reducing pain in healthy individuals are well documented, but the underlying mechanisms are unclear. The aim of this study was to explore the mechanisms of exercise-induced hypoalgesia (EIH) using evoked potentials. **METHODS:** Somatosensory evoked potentials (SEPs) and pressure pain thresholds (PPTs) were assessed in 16 healthy volunteers before and after a 3 min sustained isometric contraction of the right elbow flexors at 40% maximal voluntary force. Procedures were repeated in the same session before and after an equivalent period of quiet rest in a counterbalanced design. Pressure pain thresholds were assessed using algometry over the biceps brachii and first dorsal interosseous muscles on the right side of the body. Somatosensory evoked potentials were recorded using electroencephalography (EEG) at four sites (Cz, Fz, Pz and C3; 10-20 International System) in response to non-painful and painful electrical stimulation of the digital nerve of the right index finger. The SEP waveforms were averaged from responses to approximately 500 stimuli and the peak-to-peak amplitude of the N2P2 component of the potential was measured. Electrode impedance was recorded throughout the experiment. Effect sizes (unbiased Cohen's *d*) and 95% confidence intervals were calculated to permit statistical comparisons between conditions. **RESULTS:** There was a large and moderate effect, respectively, of isometric exercise on increasing PPT at the bicep (0.84, 0.45 to 1.3) and first dorsal interosseous muscles (0.56, 0.28 to 0.9), indicative of EIH. There was no effect of exercise on SEP amplitude (-0.02, -0.23 to 0.19). This was despite clear modulation of the N2P2 peak-to-peak amplitude in response to different intensities of electrical stimulation and accompanying pain for each participant (-1.18, -1.89 to -0.58). **DISCUSSION:** N2P2 peak-to-peak amplitude did not change following exercise, although increased PPTs demonstrated clear EIH. The most parsimonious explanation is that electrically activating the axons of sensory neurons to evoke pain potentials in the EEG bypassed their receptors (nociceptors) and that these receptors are involved in EIH. We are currently using laser evoked potentials to confirm if changes in the sensitivity of peripheral nociceptors might be the primary mechanism of EIH.

Symposium 5: Coordination and Somatosensory Function

Session Chair: Paul Hodges

11:30	Ingvars Birznieks	Somatotopic mismatch of hand representation following stroke
11:45	Stephen Redmond	Decoding tactile afferent activity to obtain an estimate of instantaneous force and torque applied to the fingerpad
12:00	Wolbert van den Hoorn	Effect of noxious stimulation to the leg or back on muscle synergies during walking
12:15	Francois Hug	Motor adaptations to pain during a bilateral task: does the cost of using the non-painful limb matter?
12:30	Nicholas O'Dwyer	Coordination of whole body movements is governed by linear dynamic inter-joint relations with a single degree of freedom
12:45	Trevor Allen	The senses of active and passive force at the human ankle joint

Somatotopic mismatch of hand representation following stroke

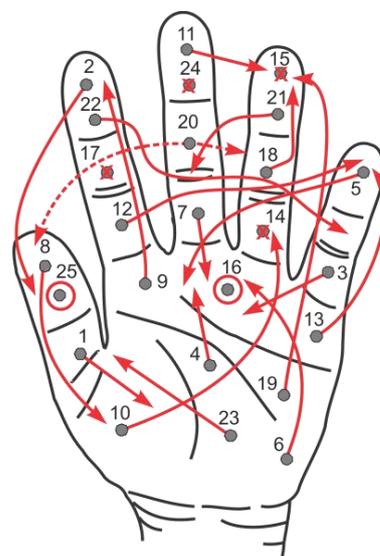
Ingvars Birznieks^{1,3,4}, Mohammad Rehmanjan², Sarah McIntyre⁴, Tuan Nguyen⁵, Stanley Levy⁶, Kylie Steel³, Inara Logina⁷, Gunnar Wasner⁸, Richard Vickery^{1,4}.

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Recovery of the hand dexterity after stroke cannot be achieved in absence of the tactile sensory information. Well organised somatotopic representation of the hand is required to interpret input from cutaneous mechanoreceptors. Some reports in the literature have identified isolated cases* describing patients with various distortions of somatotopic representation after stroke. The aim of current study was to test a group of patients to demonstrate whether such dysfunction may be found by systematic testing.

Any cognitively able patient willing to participate who had any kind of hand function impairment was accepted for testing. The criteria were not restricted to patients with known sensory deficits, patients with certain lesions or to certain time-frames post-stroke.

The order of somatotopic representation of the hand was assessed by testing mismatch between the test site where the point-type stimuli were applied and location on the skin where stimuli were perceived by the patient. Twenty-five predefined sites on the glabrous skin of each hand were tested. Out of 20 patients tested, five patients were identified to show three forms of somatotopic mismatch: (1) scrambled somatotopic representation, high detection thresholds; (2) orderly distorted somatotopic representation, close to normal detection thresholds; and (3) labile, changing somatotopic representation. None of the patients were aware of this pathology prior to our testing. Figure illustrates localisation mismatch in one of the patients. Arrows originate from the centre of each test site where stimulus was applied and terminate at the location where stimulus was felt.



While mismatch in somatotopic representation is reported to be present many years after stroke we have retested one patient 9, 21 and 60 month after stroke and observed that normalisation of somatotopic maps is possible. Whether there is a critical time period for intervention and whether somatotopic representation order may be achieved in some, but not other patients is not known. This indicates the need for clinical tests to diagnose such patients during routine clinical examination and design new rehabilitation strategies to enable or to improve the recovery of sensory and sensorimotor function after stroke.

*including our own: Birznieks I, Logina I, Wasner G. Somatotopic mismatch following stroke: a pathophysiological condition escaping detection. *BMJ case reports*, 2012 Oct 6.

Decoding tactile afferent activity to obtain an estimate of instantaneous force and torque applied to the fingerpad

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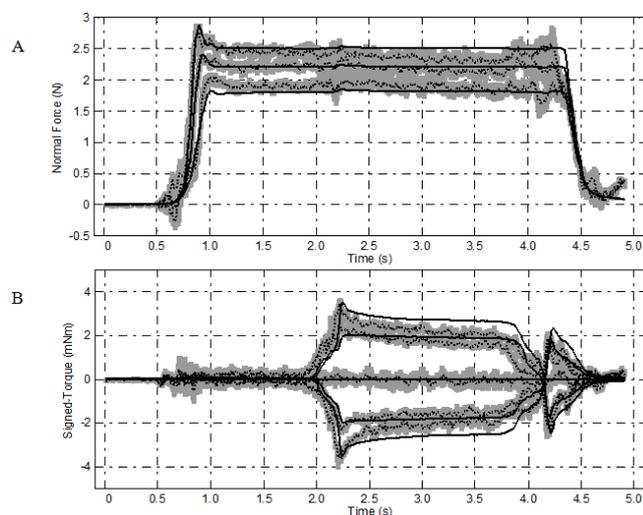
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Introduction: Dexterous manipulation is not possible without sensory information about object properties and manipulative forces. Fundamental neuroscience has been unable to demonstrate how information about multiple stimulus parameters may be extracted, concurrently, in real time, from a population of tactile afferents. This is the first study to demonstrate this using spike trains recorded from tactile afferents innervating the monkey fingerpad.

Methods: A multiple regression model, requiring no *a priori* knowledge of stimulus onset times or stimulus combination was developed to obtain continuous estimates of instantaneous force and torque magnitude. The stimuli consisted of a normal force ramp (to a plateau of 1.8, 2.2 or 2.5 N) on top of which 2.0 or 3.5 mNm torque was applied in either a clockwise or anti-clockwise direction. The model inputs were sliding windows of binned spike counts recorded from each afferent. Models were trained and tested by 15-fold cross validation to estimate instantaneous normal force and torque over the entire stimulation period.

Results: Using the spike trains from 58 SA-I and 25 FA-I afferents, the instantaneous normal force and torque could be estimated with small error.

The figure shows the results of combined SA-I/FA-I models (100 ms window): (A) Estimate of normal force for plateau of 1.8, 2.2, 2.5 N. Dotted line is median estimate, solid line is target, grey region is interquartile range. (B) Estimate of signed-torque for plateau of -3.5, -2.0, 0, +2.0, +3.5 mNm.



Discussion: This study demonstrates that instantaneous force and torque parameters could be reliably extracted from a small number of tactile afferent responses in a real-time fashion with stimulus combinations that the model had not been exposed to during training. Analysis of the model weights may reveal how interactions between stimulus parameters could be disentangled for complex population responses and could be used to test neurophysiologically relevant hypotheses about encoding mechanisms.

Effect of Noxious Stimulation to the Leg or Back on Muscle Synergies During Walking

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Introduction Pain alters motor control. This has been well documented during single-joint isometric tasks that provide few options for the central nervous system to adapt. Less is known for walking, which involves multiple joints, and thus various possibilities to adapt. With walking, activity of muscle groups is coordinated according to muscle synergies. 4-6 muscle synergies are reported to underlie control of gait. Each is associated with functional subtasks. The number of synergies provides information about the complexity of control, whereas changes in the composition/activation of synergies can indicate whether and how the control of these motor subtasks is altered. Leg muscle synergies are important to maintain walking speed, whereas trunk muscle synergies are related to maintenance of upright posture. We studied the effect of experimental muscle pain on muscle synergies during treadmill walking. We compared two pain locations; medial gastrocnemius (responsible for propulsion); and erector spinae (responsible for posture). We hypothesized that muscle synergies related to the maintenance of walking speed are robust to pain, regardless of its location, in contrast to trunk synergies.

Methods 16 volunteers walked on a treadmill at 0.94 ms^{-1} during 5 conditions; control (Control); low back pain (LBP); Washout LBP; calf pain (CalfP); and Washout CalfP. Electromyographic (EMG) recordings were made from 12 leg muscles and 5 trunk muscles on the right side. Muscle pain was induced by hypertonic saline injection into the right erector spinae muscle at L3 or the right medial gastrocnemius muscle. 15 complete consecutive stride cycles were selected for analysis. EMG data were filtered (band-pass: 20-750 Hz), rectified and smoothed (low-pass: 9 Hz) and normalised to the average of the peaks from the Control condition. Muscle synergies were extracted using Non-Negative Matrix Factorization. The similarity of the extracted synergies across conditions was tested by cross-validation procedures.

Results Five muscles synergies accounted for >90% of the variance of all recorded muscles for each condition. Muscle synergy vectors (i.e. composition of muscle synergies) extracted for the Control condition could account for >81% of variance of the other conditions. Muscle synergies were altered very little in some participants ($n=7$ for LBP; $n=10$ for CalfP), but were more affected in the others ($n=9$ for LBP; $n=6$ for CalfP). No systematic differences between pain locations were observed. Considering all participants, synergies related to propulsion and weight acceptance were largely unaffected by pain, whereas synergies related to trunk control and leg deceleration were more affected.

Discussion The robustness of propulsion and weight acceptance synergies can be explained by the fact that they are important to maintain walking speed. In contrast, trunk flexion/extension synergies were more altered during pain in the calf and lower back muscle, but with high between-participants variability. Overall, these changes in muscle coordination involve a participant-specific strategy that is important to further explore as it may explain why some people are more likely to develop persistence of a painful condition.

Motor adaptations to pain during a bilateral task: does the cost of using the non-painful limb matter?

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Introduction: During a force-matched bilateral task, when pain is induced in one limb, a shift of load to the non-painful leg is observed. This is hypothesized to be a purposeful strategy to reduce load within the painful region to protect from further pain and/or injury. The primary aim of this study was to test the hypothesis that the adaptation to pain (i.e. modified force sharing between legs) depends on the mechanical efficiency of the non-painful leg. In order to test this hypothesis, we first determined whether force sharing between legs during a pain-free baseline condition adapts to account for the change in mechanical efficiency of one leg, in the absence of conscious awareness of this change.

Methods: We manipulated the mechanical efficiency (strength) of the non-painful leg in a virtual manner by imposing scaling factors: 1, then 0.25, 0.75 to decrease mechanical efficiency – *Experiment I*; 1, then 1.33 and 4 to increase mechanical efficiency – *Experiment II*. Thirty-five participants (18 and 17 for *Experiment I* and *II*, respectively) performed a series of 3 submaximal bilateral isometric plantarflexions with each scaling factor during 2 conditions (Baseline and Pain). Pain was induced by injection of hypertonic saline into the soleus.

Results: Force was equally distributed between legs during the Baseline contractions (the laterality index was close to 1; *Experiment I*: 1.16 ± 0.33 , $P=0.19$; *Experiment II*: 1.11 ± 0.32 , $P=0.36$), with no significant effect of Scaling factor (both experiments, $P=0.84$). The laterality index was affected by Pain such that the painful leg contributed less to the total plantarflexion force (*Experiment I*: 0.88 ± 0.40 , $P<0.001$; *Experiment II*: 0.74 ± 0.25 , $P<0.001$), regardless of the efficiency of the non-painful leg. When compared to the force produced during baseline of the corresponding scaling condition, a decrease in force produced by the painful leg was observed for all scaling factors, except for scaling 0.25.

Conclusion: These data highlight that regardless of the overall mechanical cost, the nervous system appears to prefer to alter force sharing such that force produced by the painful leg is reduced relative to the non-painful leg. This supports the notion that protection of painful tissue is prioritized.

Coordination of whole body movements is governed by linear dynamic inter-joint relations with a single degree of freedom

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Introduction The extent of the computational challenge posed for the central nervous system by the many degrees of freedom available at the joints of the human body has long been recognised and the notion of simplifying movement control by reducing the number of controlled variables has been the subject of a substantial body of research. Using the powerful and popular technique of principal component analysis (PCA), numerous studies have shown that both muscle signals and multi-segmental kinematic signals are highly coupled and may be decomposed into independent modular components or synergies, supporting the idea of modular control of movement. PCA is based on a matrix of either correlations or covariances between all pairs of signals in the analysed data set. A primary limitation of such matrices is that they do not account for phase differences or frequency-dependent variations in amplitude ratio between signals, yet such properties are widespread in relations between signals in the sensorimotor system. In such instances, low correlations may be obtained and signals may appear 'independent' despite the presence of a dynamic linear relation between them. To address this limitation, we have used PCA based on a matrix of overall coherence square values between signal pairs, derived from linear systems analysis (Wang *et al.*, 2013).

Methods Data sets of whole body joint angles were studied in three different tasks: 1) 40 angles from 22 adults (11 M, 11 F) walking overground at preferred speed; 2) 30 angles from 16 adults (8 M, 8 F) before and after five days of practice (25 x 1 minute trials per day) on a slalom skiing simulator; 3) 38 angles from 30 adults (5 M, 5 F beginners; 5 M, 5 F intermediate; 5 M, 5 F experts) performing Latin dance sport (steps from the Cha-Cha-Cha).

Results For all three datasets, the first principal component accounted for $\geq 80\%$ of variance of the data while the next component accounted for $< 5\%$ of variance, showing that the datasets effectively contained only one degree of freedom. In contrast, conventional PCA based on correlation coefficients indicated multiple principal components for all datasets.

Discussion The coordinative relations between joint angles are therefore considerably more complex than the simple algebraic relations described by linear regression analysis and correlation coefficients. The coordination can instead be described by linear dynamic relations that accommodate frequency-dependent amplitude ratios and phase shifts. Such dynamic relations yield coordinative structures with a single functionally significant degree of freedom, consistent with a single program of movement.

References Wang X, O'Dwyer N, Halaki M, Smith R (2013) Identifying coordinative structure using principal component analysis based on coherence derived from linear systems analysis. *Journal of Motor Behavior* 45(2):167-179.

The senses of active and passive force at the human ankle joint

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Introduction: The sense of muscle force is thought to be derived from signals originating from both peripheral receptors and centrally-derived copies of the motor command, with centrally-derived signals playing the dominant role. However recent evidence suggests a greater contribution from peripheral receptors. The purpose of this study was to test for a contribution from peripheral receptors to force sense at the ankle joint. **Methods:** Ten young adults (5 male and 5 female, mean age 22yrs) participated. First the angle-torque relation of ankle extensors of both legs was determined using isometric Maximum Voluntary Contractions (MVCs). A series of force matching trials were then carried out in which each participant was required to push (plantarflex) on the footplates with both feet at the same time until a target force was reached in the reference foot (20% MVC) using visual feedback. When forces felt to be the same the participant pressed a thumb operated switch. A control series of matching trials were done with both feet positioned at the same ankle angle. This was followed by matching trials in which one foot was positioned on ascending limb of the angle-torque relation (shorter muscle lengths), while the other foot was positioned on the descending limb (longer muscle lengths), such that the force capacity was similar. **Results:** During matching the active force generated by the leg placed at longer length was not significantly different from that generated by the leg at the shorter length. However, when the contribution of passive force was included in the calculation of matching errors, the muscle at the longer length produced significantly higher forces. **Discussion:** Force matching errors were in the opposite direction to that predicted if stretch receptors were contributing to force sense at the ankle joint. The passive component of the force produced in the stretched leg appeared to be ignored during force matching. The results support a central mechanism of force sense when muscles are active at the ankle joint.

Symposium 6: Sensorimotor Learning and Plasticity

Session Chair: Andrew Cresswell

2:30	Emma	Burns	Short- and long-latency afferent inhibition are reduced following acute muscle pain
2:45	Saeid	Mehrkanoon	Network Plasticity inferred from Resting Brain Dynamic Functional Connectivity
3:00	Xin	Xu	Naïve physics of heading control
3:15	Ann-Maree	Vallence	Reproducibility of neuroplastic responses induced by continuous theta-burst stimulation.
3:30	Lynley	Bradnam	Modulation of the cerebellum using theta-burst stimulation in people with cervical dystonia
3:45	Guy	Wallis	A self-organising model of the Bayesian brain

Short- and long-latency afferent inhibition are reduced following acute muscle pain.

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Introduction: It is well documented that pain affects sensorimotor function, yet the mechanisms that underpin these effects remain unclear. Short- and long-latency afferent inhibition (SAI and LAI) are intracortical mechanisms that could plausibly contribute to altered sensorimotor function in pain. Yet, the effect of acute muscle pain on these mechanisms has not been examined. Thus, in this study we investigated the effect of acute muscle pain on SAI and LAI.

Methods: Twenty-two healthy, right-handed volunteers participated (9 male, age = 22.6 ± 7.8 years). Corticomotor output (motor evoked potentials, MEPs), SAI and LAI were investigated using transcranial magnetic stimulation (TMS). Compound muscle action potentials (Mwaves) were recorded to account for changes in excitability occurring at the muscle and neuromuscular junction. Pain was induced by infusion of hypertonic saline (5%, bolus 0.2mL followed by rate of 6mL/hour) into the first dorsal interosseous (FDI) of the right hand. Electrical activity of FDI was recorded using surface electromyography and data collection was performed i) at baseline, ii) during pain (measurement commenced once pain reached an NRS score of 5/10), iii) post pain (once pain had returned to 0/10) and iv) follow-up (15 minutes after pain had returned to 0/10).

Results: Corticomotor output was reduced during (baseline vs. during, $p = 0.039$) and immediately after pain (baseline vs. post, $p = 0.049$), but returned to baseline 15 minutes later (baseline vs. follow-up, $p = 0.14$). Mwave amplitude was reduced during pain and remained reduced for the duration of the experiment (baseline vs. during, post, follow-up; all $p < 0.001$). The induction of muscle pain had no effect on SAI or LAI during pain (baseline vs. during, SAI: $p = 0.59$; LAI: $p = 0.45$), however SAI was reduced immediately after the resolution of pain (baseline vs. post, $p = 0.037$). These values returned to baseline at the 15-minute follow-up (baseline vs. follow-up, $p = 0.21$). In contrast, LAI was unchanged immediately following the resolution of pain (baseline vs. post, $p = 0.064$) but was significantly reduced 15 minutes later (baseline vs. follow-up, $p = 0.005$).

Discussion: In addition to confirming previous observations of reduced corticomotor output, these novel data demonstrate reduced SAI and LAI in response to acute muscle pain. As SAI and LAI are thought to reflect the integration of afferent information between the sensory and motor cortices, our findings suggest that following pain sensorimotor integration is disturbed. This disturbance may signify a deficiency in cholinergic inhibition within the motor cortex following cessation of the painful stimulation. Alternatively, reductions in SAI or LAI may arise as a result of earlier cortical responses to pain, such as reductions in sensory cortex excitability or increases in GABAergic inhibition. Although the relationship between reduced SAI, LAI and sensorimotor function during pain was not elucidated, these results suggest that the integration of sensorimotor information at the motor cortex may be compromised following resolution of pain.

Network Plasticity inferred from Resting Brain Dynamic Functional Connectivity

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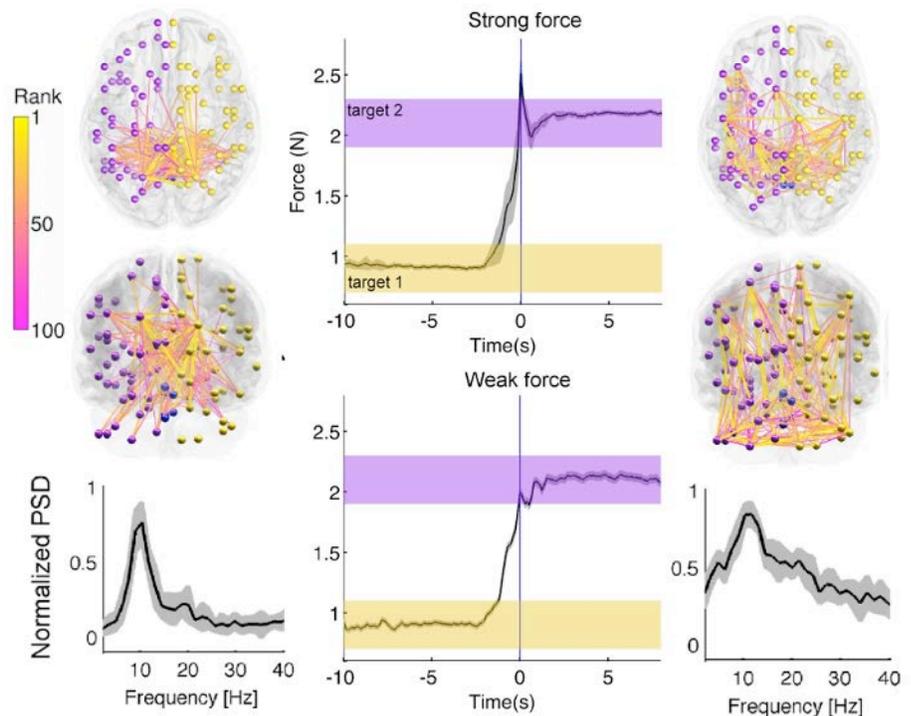
3. Human Motor Control Laboratory, University of Tasmania

Introduction Neural plasticity at the system level is reflected as the ability of the brain to reorganize its intrinsic functional integration and segregation using a task performance, e.g. motor skill learning. Here, we investigated whole-brain resting-state (RS) functional connectivity (FC) patterns in source space before and after motor skill learning to identify network plasticity at mesoscopic level.

Methods Twenty healthy adults participated in this study. The task design involved 10-min eyes closed RS as a baseline, 20-min motor skill learning, and 10-min eyes closed RS as a test. Each subject performed twenty motor learning trials. Source reconstruction was performed to localize the brain sources with respect to the acquired 64-channel surface EEG. A time-frequency technique was used to estimate whole-brain FC at multiple timescales. Principal component analysis (PCA) was used to extract connectivity patterns across subjects.

Results We found five networks with distinct spatiotemporal patterns at multiple frequencies. Enhanced cortico-cerebellar FC with increased power spectrum (5Hz-20Hz) was apparent after motor learning (Figure 1, right column), whereas its corresponding network derived from the first RS showed the default mode network (Figure 1, left column) oscillating at 10 Hz. The movement error (or an overshoot) occurred at $t=0$ s in the first 9 trials (middle column, top panel) was disappeared in the remaining 11 learning trials (middle column, bottom panel).

Figure 1. RS FC patterns (left and right columns), force profile (middle column).



Discussion We have analyzed source-space RS FC patterns before and after motor skill learning. The results imply that region-based connectivity and intra-region communication together shape large-scale network plasticity and dynamics, mirroring principle mechanisms underlying motor skill learning. The present study hence signified that mesoscopic changes in network connectivity owing to the motor skill learning gives insight into the system level plasticity mechanism, and hence behavioral improvement performance.

Naïve Physics of heading control

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Introduction The authors have previously demonstrated that in the absence of visual feedback, subjects treat a vehicle steering-wheel like a velocity control device for position, rather than an acceleration control device (which is what it actually is). In this study we asked what forms of visual feedback are required to trigger the correct response by providing continuous but limited forms of visual feedback. In the experiment subjects were exposed to a virtual environment with no optic flow, moderate optic flow, and dense visual information including a normal road surface, and they were then asked to steer through a series of gates.

Methods Participants operated a fixed-based driving simulator with force-feedback steering wheel and large-screen display. The simulation ran at 60Hz. The vehicle's steering wheel angle, heading angle, direction vector, etc. were recorded once per frame. Six subjects participated in the experiment.

Results and discussion

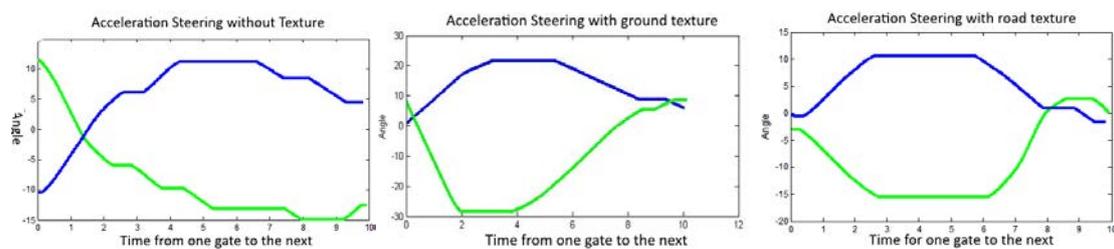


Figure 1. One subject's heading changes during driving from one gate to the next in three conditions (Left – no optic flow, Middle – moderate optic flow, Right – dense optic flow). Blue line and green line show the subject's heading changes when approaching to two different gates, respectively.

In the presence of optic flow information subjects chose to approach the gates with the opening aligned with their fronto-parallel plane. However, in no-optic-flow condition subjects demonstrated a significantly different behaviour (see figure 1). A repeated-measure ANOVA on heading changes revealed that the heading changes in all three conditions were significant different from each other. Post-hoc tests indicated that heading changes in the no-optic-flow condition were reduced compared to that in the moderate-optic-flow condition ($p = 0.073$), and that on the dense-optic-flow condition ($p = 0.003$).

The results support earlier work suggesting that in the presence of impoverished visual feedback, subjects fall back on an incorrect model of a vehicle's dynamics, but that they are able to utilise optic flow information to correct the aberrant behaviour. It would appear therefore, that drivers do not need to understand a vehicle's true dynamics as long as they have access to optic flow information.

Reproducibility of neuroplastic responses induced by continuous theta-burst stimulation.

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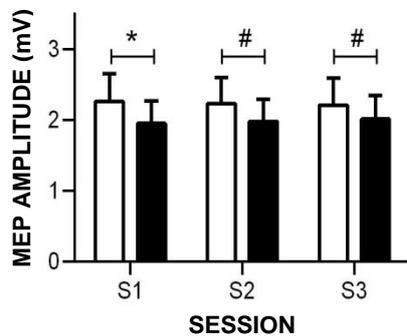
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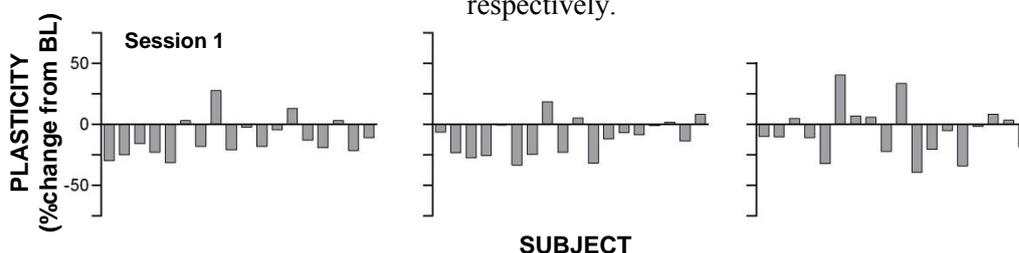
Introduction: The therapeutic potential of non-invasive brain stimulation (NIBS) is dependent on the development of protocols that induce robust and functionally relevant cortical changes that outlast the period of stimulation. A current limiting factor of NIBS is intra- and inter-subject variability in NIBS-induced neuroplastic responses. At present, there are very little data on intra-subject reliability of continuous theta-burst stimulation (cTBS)-induced neuroplastic responses.

Methods: To investigate the reproducibility of neuroplastic responses induced by cTBS, motor evoked potential (MEP) input-output (IO) curves were obtained before and after cTBS in three separate experimental sessions.

Results: First, significant MEP suppression was observed following cTBS at the upper end of the IO curve (150-180% resting motor threshold; RMT). At 150% RMT, significant MEP suppression and strong relationships between neuroplastic responses were observed across experimental sessions.



Left: Raw MEP amplitudes probed at 150% RMT before (open) and after (filled) cTBS in each of the three sessions. * and # denote statistical significance at $P < .012$ and $P < .05$ respectively.



Bottom: Subject response variability to cTBS probed 150% RMT in each of the three sessions. Data represent mean percentage change of post-cTBS MEP amplitudes from baseline, with positive and negative values indicating an increase and decrease in MEP amplitudes following cTBS respectively.

Second, a significant linear relationship was evident between cTBS-induced MEP suppression (probed at an intensity that evoked MEPs ~50% of the maximal MEP) and the interval between experimental sessions.

Discussion: The current study provides the first comprehensive investigation of the between session reproducibility of cTBS-induced neuroplastic responses. Results suggest that 150% RMT is the most reliable TMS intensity to probe cTBS-induced neuroplastic responses and provide some evidence to suggest that short intervals between experimental sessions administering NIBS protocols is associated with increased NIBS-induced plasticity responses.

Modulation of the cerebellum using theta-burst stimulation in people with cervical dystonia

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Introduction: There is emerging evidence that cervical dystonia is a neural network disorder with the cerebellum as a key node. Therefore, the cerebellum may provide a novel therapeutic target for non-invasive stimulation in this population. This study aimed to assess effects of intermittent theta-burst stimulation (iTBS) of the cerebellum on dystonia symptoms, quality of life and cortical neurophysiology using transcranial magnetic stimulation (TMS).

Methods: Sixteen participants with cervical dystonia were randomised into real ($n = 8$) or sham ($n = 8$) iTBS groups. The intervention was delivered at a similar time of the day for ten consecutive working days. TMS was used to assess motor-evoked potentials (MEPs) and cortical silent periods (CSPs) from the upper trapezius muscle contralateral and ipsilateral to the direction of tonic head rotation. Dystonia severity and quality of life were assessed by specific questionnaires (TWSTRS, CDQ24). **Results:** The primary outcome measure, TWSTRS score at POST 1, was significantly reduced in the real iTBS group ($X^2(2) = 8.86, P = 0.012$), but not in the sham iTBS group ($X^2(2) = 0.67, P = 0.72$) as revealed by the Friedman test. A Wilcoxon post hoc test revealed the TWSTRS was reduced by iTBS at MID ($-5.7 \pm 0.9, P = 0.018$) and POST 1 ($-4.4 \pm 1.2, P = 0.042$). Comparison between Groups (Kruskal-Wallis) revealed no difference at baseline or either follow-up point (all $P > 0.66$). The pain subsection of the TWSTRS found a significant difference over time for iTBS ($X^2(2) = 9.74, P = 0.008$), but not for sham TBS ($X^2(2) = 4.26, P = 0.12$). Post hoc tests showed a significant reduction in pain at both MID and POST 1 (both $P < 0.018$). Comparison between groups found a significant difference at POST 1 ($P = 0.040$) but not at PRE or MID (both $P > 0.18$). For the CDQ-24, there was a difference across time for iTBS ($X^2(4) = 11.14, P = 0.025$), but not sham TBS ($X^2(4) = 4.69, p = 0.32$). Post hoc tests revealed a reduction by iTBS compared with baseline at each assessment point (all $P < 0.01$). The group comparison revealed a significant difference between real and sham iTBS at POST 3 ($P = 0.04$), but no difference between Groups at PRE, MID or POST 1 (all $P > 0.16$). Repeated measures ANOVA revealed no effect of GROUP, SIDE or TIME for MEPs or CSPs recorded from the upper trapezius (all $P > 0.21$). **Conclusion:** Intermittent TBS to the cerebellum may provide a novel treatment intervention for people with cervical dystonia. A small but significant clinical improvement was observed at the end of the intervention period and quality of life was increased after 10 sessions and this improvement was still apparent 12 weeks later.

A self-organising model of the Bayesian Brain

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In order to interact with our environment, our brain is tasked with making accurate estimates about the current and future state of the world, such as where objects are relative to us and where they will be in the near future. Although our various sensory systems can offer important cues upon which to build such an estimate, they are far from infallible and may even offer inconsistent estimates. One of the outstanding questions in neuroscience is how the brain integrates these sources of information to arrive at an optimal estimate. One thing that is clear is that such estimates are affected by both current sensory input and prior, often context-dependent, cues derived from past experience. Bayesian inference has been offered as a framework within which to optimally integrate these myriad cues. Although the power and generality of its use is unquestioned, scientists currently lack a biologically plausible model of how the framework might be realised in the brain. I describe the basis for such a model. I go on to explain how the model offers a range of additional attractive emergent properties including robustness, adaptability and the maximal retention of information for a given neural resource. I close by describing the types of predictions such a model makes, and summarise behavioural evidence consistent with these predictions.

Poster Session

P1: Learning and Adaptation			
4-5pm	P1.1	Siobhan Fitzpatrick	Non-invasive cervical direct current stimulation changes properties of the H-reflex recruitment curve in the upper limb.
	P1.2	Hossein Jahanabadi	Constraints upon learning novel muscle activation patterns after virtual tendon transfer.
	P1.3	Kwee-Yum Lee	Perceptual and motor learning determines human stick balancing skill
5-6pm	P1.4	Michaela Bruton	Absence of sex differences in performance of a novel whole body movement task before and after an equal volume of practice
	P1.5	Matthew Feldman	Intermittent muscle contractions of one limb reduce the force generation capacity of the opposite limb
	P1.6	Hesam Alavi	Assessing the role of the motor cortex in visuomotor memory

P2: Pain/Clinical			
4-5pm	P2.1	Peter Poortvliet	Deep brain stimulation programming experiences for non-motor complications in parkinson's disease
	P2.2	Edith Elgueta-Cancino	The relationship between motor cortex organization, sensation, pain and movement in chronic low back pain
5-6pm	P2.3	Dean Mayfield	Achilles tendon compliance limits force augmentation during the summation of isometric force
	P2.4	Matthew Sweeny	Movement Variability in the Gait of Parkinson's Sufferers
	P2.5	Holly Thompson	The effects of unilateral pain and perturbation on gait symmetry

P3: Neuromechanics			
4-5pm	P3.1	James Day	A pilot study investigating the relationship between tibialis anterior muscle fascicle dynamics and muscle spindle firing patterns.
	P3.2	Brent Raiteri	Ultrasound reveals negligible co-contraction during isometric plantar flexion and dorsiflexion despite the presence of antagonist EMG activity
	P3.3	Julian Saboisky	Optimal length for tongue protrusion force in humans
5-6pm	P3.4	Rafeef AlJuraifani	Location and characteristics of stiffness change related to voluntary contraction of the urethral sphincter muscles quantified with supersonic shear i
	P3.5	Hans Kainz	Survey of methods for lower limb joint definitions in subject-specific models

P4: Other SMC			
4-5pm	P4.1	Briar Rudsits	How fast can we really move our legs?
	P4.2	Li-Ann Leow	The role of the supplementary motor area in beat-based timing
	P4.3	Leila Nuri	Reaction time and anticipatory skill of athletes in open and closed skill-dominated sport
5-6pm	P4.4	Anthony Tsay	Sensory basis of limb position sense differs between pointing and matching
	P4.5	Luu Billy	Changes in the inspiratory loading reflex during postural activation of scalenes in humans.
	P4.6	Andrew Claus	With sudden axial perturbation, posture is maintained by a rapid response, which is mediated by body weight.
	P4.7	Greg Anson	Does perception of time alter under hypnosis?

Non-invasive cervical direct current stimulation changes properties of the H-reflex recruitment curve in the upper limb.

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Introduction: Trans-spinal direct current stimulation (tsDCS) over the thoracic spinal cord can modify post activation depression (PAD) of the soleus H-reflex¹, and shift the H-reflex recruitment curve². After cervical tsDCS, maximal amplitude and latency of the upper limb H-reflex are reported as unchanged³. However, PAD has not been tested, nor have other properties of the H-reflex recruitment curve. Here we aimed to further characterise the effects of cervical tsDCS on the H-reflex.

Methods: Subjects (n=7; 3F) received 20 min of tsDCS or sham (1 min of tsDCS) stimulation on 2 days. TsDCS comprised of 3mA of DC passed between 30cm² saline-soaked sponge electrodes positioned on the anterior side of the neck under the chin (anode) and posteriorly over the 7th cervical vertebra (cathode). Median nerve stimulation over the cubital fossa elicited M and H waves in the relaxed right flexor carpi radialis (FCR). H-reflex recruitment curves were recorded by increasing stimulus intensity in steps of 0.05-0.1 mA (2 stimuli per step) from below motor threshold to above the intensity needed to elicit maximal H-reflexes (Hmax). The maximal M wave (Mmax) was also obtained. To measure PAD, 20 H-reflexes (50% Hmax) were recorded at each of 1Hz (H_{1Hz}) and 0.1Hz (H_{0.1Hz}). Testing was performed before (controls) and at two time-points after tsDCS or sham (T1: 0-20 min; T2: 20-40 min). For analysis, sigmoidal curves were fitted to the H-reflex recruitment data and Hmax, slope, S_{thresh}, S50 and S99 (stimulus intensities to elicit H-reflexes of 5%, 50% and 99% Hmax respectively) were calculated. The ratio H_{1Hz}/H_{0.1Hz} provided a measure of PAD. Two-way repeated measures ANOVAs (conditions X time) and Bonferroni corrected post-hoc tests were used for statistical analyses.

Results: After tsDCS, but not after sham stimulation, the slope of the H-reflex recruitment curve was significantly decreased from control values at both T1 (p=0.049) and T2 (p=0.01). At T2, a decrease in S_{thresh} (p=0.042), and an increase in S99 (p=0.0024) also occurred only after tsDCS. There were no differences between tsDCS and sham conditions for Hmax, S50 or PAD.

Discussion: H-reflex recruitment in FCR was altered following cervical tsDCS. The mechanism is unclear as a reduction in recruitment slope is consistent with either a reduced sensory volley through presynaptic inhibition or a decrease in gain of the motoneurone pool.

1. Winkler, Hering & Straube *Clin Neurophysiol.* 121:957-961, 2010
2. Lamy, Ho, Badel, Arrigo and Boakye *J Neurophysiol.* 108(3):906-914, 2012
3. Lim & Shin *NeuroReport.* 22:819-823, 2011

Original coordination between muscles is maintained after Virtual Tendon Transfer Hossein Jahanabadi (ujhahan@uq.edu.au)¹, Timothy Carroll¹, Aymar de Rugy^{1, 2}

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To produce a given force, the central nervous system (CNS) appears to share the load optimally between multiple muscles. However, to what extent this behaviour is constrained by the structure of the CNS is unknown. One way to probe this is to change the biomechanics at muscle level and test whether the nervous system is able to generate new muscle coordination patterns that are optimal for the novel biomechanics. We recently developed a virtual biomechanics technique that enables reconstruction of forces produced at the wrist joint in real time from surface electromyographic recordings. We used this technique in a previous study to test the CNS response to a range of novel wrist biomechanics, including, virtual elimination of a muscle, addition of signal dependent noise to a muscle, and the simulation of the biomechanics of a different forearm posture. In all those situations, we found that the muscle activities recorded over approximately 1.5 hours of practice were better described by a linear scaling of the original muscle patterns that were no longer energetically efficient. Here, we probed more dramatic alteration of biomechanics that changed the functional arrangement of muscles, and applied this change over a longer period (i.e., an entire day) to give more chance to the CNS to re-optimize his behaviour. For instance, by switching the pulling directions of two antagonistic muscles, Flexor Carpi Radialis (FCR) and Extensor Carpi Ulnaris (ECU), we created a condition that dramatically changed the coordination required between muscles. Simulation of muscle activities re-optimized for this condition predicts that the activity of the switched muscles should also be switched, while the activities of other muscles activity should remain relatively unaffected. This implies that FCR and ECU should be coordinated with muscles other than those to which they were normally coordinated with. In contrast, simulation of a linear scaling of the original muscle pattern predicts that FCR and ECU should maintain the same coordination with their original neighbour muscles, Extensor Carpi Radialis longus (ECRL) and brevis (ECRB), and consequently, that the activities of both pairs of muscles should be switched simultaneously. Our results indicate that performance, quantified by the minimal distance from the target and by the number of target reached, improved for all subjects during practice. In contrast, changes in muscle activities observed for the target reached were relatively stable over practice, and were more consistent with a linear scaling of baseline muscle patterns than with a re-optimized behaviour. Indeed, ECRL and ECRB activities were systematically switched to maintain their original coordination with FCR and ECU, despite this behaviour being clearly suboptimal from an energetics point of view. However, we observed substantial departure from prediction from a linear scaling, in the form of additional co-contraction, for target directions that were orthogonal to the axis defined by the switched muscles (FCR and ECU). Because a feedback correction using the wrong switched muscle would generate a movement in the direction opposite to that intended for those targets, we presume that the observed co-contraction is due to additional difficulties with feedback corrections. Overall, these results indicate that the CNS can improve performance when faced to virtual tendon transfer, but that this is done within the original coordination between muscles as there was no sign of re-optimized coordination even after an entire day of practice.

Perceptual and Motor Learning Determines Human Stick Balancing Skill

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2. School of Human Movement Studies, Charles Sturt University

3. Discipline of Exercise and Sport Science, The University of Sydney

Introduction We have previously reported detailed three-dimensional (3-D) kinematic/kinetic measures and modelling of skilled stick balancing (Lee *et al.*, 2012). Herein we use the same measures to identify behavioural changes with practice to investigate learning mechanisms of skilled balancing.

Methods Nine participants practised balancing a stick (a television antenna, 52 cm, 34 g) on the fingertip of the right hand for 6 weeks. A total of 40 (20 pre- and 20 post-practice) trials of 3-D balancing motions of the tip of the stick and fingertip were collected using a motion capture system (Motion Analysis Corporation, USA).

Results After 3.5 hours of practice, the participants could balance the stick for a longer duration with significantly reduced magnitude of stick and finger movements (Figure). Irrespective of level of skill, the stick behaved like a normal non-inverted pendulum oscillating under greater-than-gravity torque. The control input parameter was the magnitude ratio between the torque applied by the participant and the torque due to gravity. Since only a narrow range of this parameter was utilised, the stick maintained the same period of oscillation regardless of practice, but showed markedly reduced magnitudes of oscillation and translation. Reduced cross-coupling errors were observed between finger and stick movements in orthogonal axes, i.e., finger motion in the antero-posterior axis became less coupled with stick tip motion in the medio-lateral axis and vice versa.

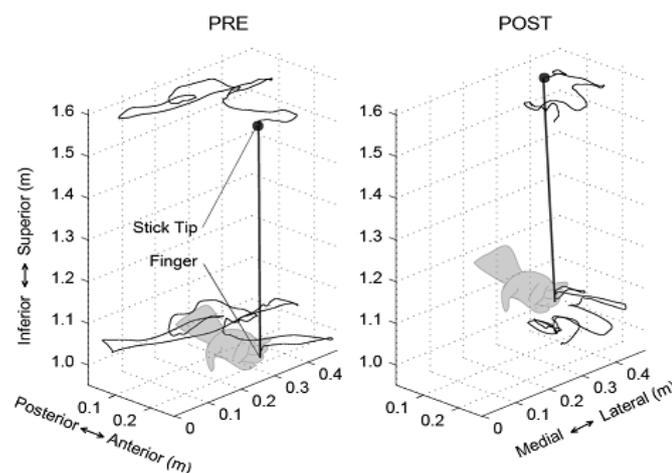


Figure. Sample 3-D trajectory of stick tip and finger over 10 s before (PRE) and after (POST) practice.

Discussion The findings indicated that improved skill was associated with more precise visual localisation of the stick and proprioceptive localisation of the finger. Acquiring this fine motor skill therefore depended on both perceptual and motor learning that enabled better estimation of sensorimotor state and greater precision of motor commands to an unvarying internal model of the stick rotational dynamics.

Reference

Lee K-Y, O'Dwyer N, Halaki M, Smith R. A new paradigm for human stick balancing: a suspended not an inverted pendulum. *Exp Brain Res* 221:309-328, 2012.

Absence of sex differences in performance of a novel whole body movement task before and after an equal volume of practice

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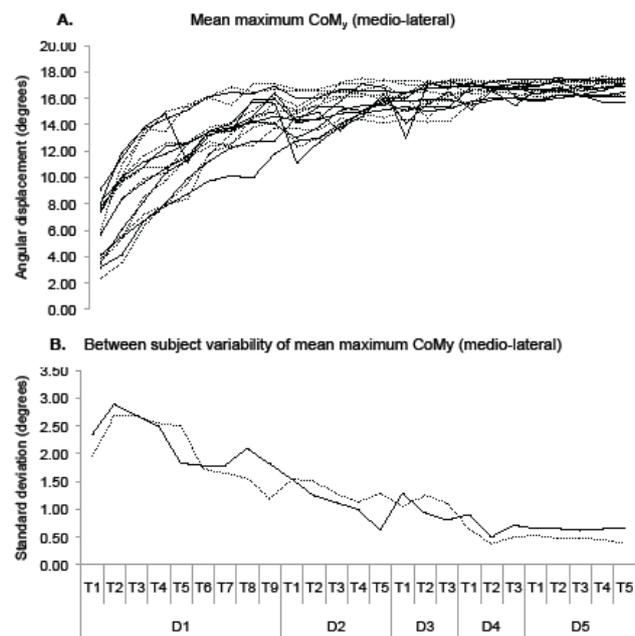
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Introduction Evidence from jumping and landing tasks suggests that experience is an important factor determining sex differences in movement, but the question whether females and males achieve similar gains from an equal volume of practice has not been addressed. The slalom skiing simulator was used here to compare the performance and rate of learning between the sexes on a novel motor task.

Methods Eight males and eight females performed five days of practice (25 x 1 minute trials per day) under instruction to make the fastest and widest movements possible on the platform. Whole body movement in three dimensions and electromyography were employed to provide a comprehensive account of movement kinematics and kinetics. Increases observed in platform frequency and amplitude, and decreases in cycle-to-cycle variability, confirmed adherence to the instructions.

Results No differences between females and males were found in the rate of learning for any kinematic or kinetic outcome variables. The figure illustrates the progression of angular displacement of the centre of mass (CoM) in the medio-lateral plane. A male performance advantage was observed for platform oscillation frequency due to the higher spring resistance settings of the apparatus for the heavier male participants, but both groups worked close to the optimal platform frequency for their mass and moved closer to that frequency with practice. Some minimal differences observed in movement kinematics between the sexes were attributable to anthropometric differences.

Discussion The major finding was that females and males showed similar initial and final performances and achieved similar gains from an equal volume of practice. We conclude that there are no explicit differences between males and females in the capacity to learn a novel motor task over the same duration of practice. The findings support the view that sex differences observed in movement commonly may be accounted for by differences in anthropometry (mass, strength, height) and prior motor experience.



A) Individual progression across days (D) and trials (T) of practice of all participants. B) Between-subject variability of this measure. Darker line: male group, lighter line: female group.

Intermittent muscle contractions of one limb reduce the force generation capacity of the opposite limb

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Introduction: When performing maximal muscle contractions on one side of the body, the same muscle on the opposite side of the body will typically exhibit unintended activity. The mechanisms underlying crossed-effects are most likely at the level of the motor cortex; however, it is unknown how differing combinations of dominant and non-dominant limb contractions modulate this unintended activity in the opposite limb. Secondly, it is unknown how repeatedly contracting the dominant limb to fatigue affects this unintended activity in the opposite limb. The aim of this study was to examine cortical excitability and muscle activity in a limb when the opposite limb is either active or at rest.

Methods: Twelve healthy subjects (age 23.4 ± 2 , all right hand preferred) participated in the experiment. Abduction force was measured at the proximal interphalangeal joint for both index fingers with Xtran 250N S-beam load-cells (Applied Measurements). Electromyography (EMG) was recorded bilaterally from the first dorsal interosseous (FDI) muscle. Transcranial magnetic stimulation was delivered to the motor cortex of the non-dominant hand using a D70² figure-of-eight coil connected to a Magstim 200² (Dyfed, UK). Stimulation was delivered when both limbs were at rest, when the dominant limb FDI was maximally contracted, when the non-dominant limb was maximally contracted, and when both limbs were maximally contracting. Stimulation in the above conditions was repeated when subjects subsequently underwent a fatigue protocol, where the dominant limb performed repeated maximal contractions until a force equal to 50% of maximal voluntary contraction could not be sustained.

Results: The main finding of the present study is that during the fatigue task, index finger abduction force significantly decreased in a similar pattern and magnitude for both limbs. Superimposed twitch measures did not significantly increase throughout the protocol. Cortical excitability (MEP) did not significantly alter when compared to control values during the fatigue protocol.

Discussion: When performing intermittent maximal contractions with one limb to fatigue, the opposite limb's ability to produce force is severely inhibited. This was unexpected as the fatigue protocol was designed to fatigue only the dominant limb. Due to the design of the experimental protocol, it is highly unlikely that the non-dominant limb experienced peripheral muscle fatigue. The bilateral limb force data thus indicates a lack of neural drive to the non-dominant limb; however, superimposed twitch measures indicate that this inhibition is not mediated by the ipsilateral primary motor cortex. Further research would utilize electrical and magnetic stimulation to examine subcortical areas and their relationship to neural coupling between limbs.

Assessing the role of the motor cortex in visuomotor memory

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Reaching to an object requires translation of visual information about its position into motor commands that bring the hand to the correct location in space. Humans can learn new internal maps for such visuomotor transformations when environmental conditions change, such as when the apparent position of the limb endpoint is rotated in virtual reality experiments. Moreover, the rate at which people learn to compensate such visuomotor rotations is higher if they have previously adapted to the same perturbation; a phenomenon known as “savings”. Although multiple brain areas are known to contribute to visuomotor adaptation, including the cerebellum, motor cortex and posterior parietal cortex, the neural mechanisms that underlie savings are unclear. Here we used cathodal transcranial direct current stimulation (tDCS) to study the role of the motor cortex (M1) in retention and savings of visuomotor learning. Fifty-one participants learned to compensate a 30° visuomotor rotation that was introduced either gradually (in 0.3° increments) or abruptly over 300 trials. They then performed 60 trials without rotation, to “washout” the adaptation, before abrupt re-exposure to the same 30° visuomotor rotation to assess savings. Cathodal tDCS stimulation or sham stimulation was applied to the left motor cortex during initial adaptation (~12 min). As cathodal tDCS decreases neuronal excitability and can impair memory formation, we predicted that savings should be impaired by stimulation if motor cortex is important for retention of the visuomotor memory. A main effect for stimulation ($F(1,47)=4.25, p=0.04$), confirmed that mean error in the first 12 savings trials was greater in tDCS than sham groups. The results show that the motor cortex is involved in the retention of visuomotor memory and contributes to faster re-learning of previously encountered visuomotor skills.

Title: Deep Brain Stimulation Programming Experiences for Non-Motor Complications in Parkinson's Disease

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Parkinson's disease (PD) is a progressive neurodegenerative disorder characterised by cardinal motor symptoms including tremor, rigidity and bradykinesia. Non-motor symptoms such as mood disturbances are not uncommon, but are not always appropriately identified by the patient or clinician. Mood disturbances may reflect changes in disease-progression, pre-existing psychiatric history, but can also be caused or aggravated by the treatment.

Deep brain stimulation (DBS) targeting the subthalamic nucleus (STN) is a well-established surgical intervention for treatment of PD. Implanted electrodes consist of four closely spaced contacts that can be individually activated (standard monopolar) or in pairs (bipolar). Adjusting the electrical parameters (i.e., voltage, pulse width, and frequency) of active contacts can further optimize the therapeutic effects.

Finding optimal configuration- and parameter-settings, to maximise benefits while minimizing side effects, is challenging. Although electrode placement accuracy has improved over the years, the distribution of the electric field surrounding active contacts can affect nearby structures, causing unwanted effects.

We report four clinical observations (3 male, 1 female) where standard programming practices showed considerable improvement of motor symptoms, however, patients also presented with self-reported mood disturbances. Although subsequent stimulation strategies improved the mood disturbances, they proved unsuccessful in retaining motor symptom alleviation.

Post-operative scans of electrode locations revealed that the optimal contacts were in proximity of the limbic STN. The subsequent change to bipolar configuration settings and a reversal of polarity of the optimal contacts, resulted in a redistribution of the electric field, away from the nearby structures.

All patients reported reductions in mood disturbances and motor symptoms. Insufficient control of some motor symptoms were addressed by steadily increasing the voltage settings, without risk of re-introducing mood disturbances.

These cases highlight the need for discussion and development of trials to determine best clinical practice for identification and management of mood disturbances and related programming methods.

The relationship between motor cortex organization, sensation, pain and movement in chronic low back pain

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Introduction: Chronic low back pain (LBP) is associated with a range of adaptive/maladaptive changes in motor control. Recent work has highlighted changes in motor and sensory cortical regions of the brain including changes in organization of the motor cortex outputs to the trunk muscles. These changes appear consistent with changes in control of the trunk muscles. It remains unknown whether these changes are predictable from features that can be assessed clinically and whether they can be changed with treatments. This study aimed to determine whether there is a relationship between clinical measures of movement, sensation and pain, and measures of motor cortex organization in people with and without low back pain.

Methods: Twenty participants with chronic low back pain (CLBP) and twenty pain free controls were assessed. Surface electromyography (EMG) electrodes, placed at level of L3 and L5, recorded myoelectric activity of lumbar erector spinae (LES) unilaterally. Motor evoked potentials (MEP) evoked by transcranial magnetic stimulation (TMS) applied to a grid on the scalp was used to map the representation of the back muscles at the motor cortex. Cortical organization was investigated by analysis of the location of center of gravity (CoG), location of peak motor evoked potentials (MEP) (i.e. “hotspots”), motor excitability and volume from the maps for individual participants and the number of the peaks in the MEP map averaged over all participants. Correlation between map features and assessment of coordination of spinal movements, pain, and sensory acuity were assessed.

Results: CLBP participants showed a reduced map volume in comparison with pain free controls for recordings at L3 ($p=0.044$) and L5 ($p=0.049$). The map CoG was more anterior in CLBP at both spinal levels (L3: $p=0.033$; L5: $p=0.037$). TMS map volume was correlated with the pain scores reported during the movement task for CLBP group (L3: $R^2=0.253$, $p=0.024$; L5: $R^2=0.446$, $p=0.001$). Fewer peaks were present in the group average TMS map for the CLBP group, but not the maps for individual participants. TMS volume at L5 is inversely related to pain (i.e. smaller map volume for those with greater pain) for individuals with both poor ($R^2=0.27$; $p=0.048$ [$n=15$]) and good ($R^2=0.86$; 0.024 [$n=5$]) performance on the movement test. Sensory features were not correlated to with motor map variables (all $R^2 p > 0.05$).

Discussion: These confirm the presence of reorganization of the representation of the paraspinal muscles at the motor cortex in CLBP. Data show both changes in location and complexity of the representation, with the latter demonstrated by fewer “hotspots”. Although reduced number of peaks was identified in the group average data, this was not observable in maps for individual participants. Some map features were related to pain and performance of the movement test. The variation in map organization in CLBP meant none of the studied clinical features could be used to predict presence of cortical organization in clinical practice.

Achilles tendon compliance limits force augmentation during the summation of isometric force

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Introduction: Force summation in skeletal muscle is highly nonlinear. Activation of a muscle in quick succession typically results in a greater than linear pattern of summation, such that the force contributed by a second stimulus is greater in amplitude and duration. The purpose of this study was to explore force summation in a muscle connected to a compliant tendon. Although contractile force is sensitive to fibre length and velocity, the sensitivity of force summation to internal shortening has yet to be established.

Methods: The triceps surae (TS) of 21 (Experiment 1) and nine (Experiment 2) healthy young adults were supramaximally activated with double pulse electrical stimuli of different interstimulus intervals (ISIs) (5-100 ms). Electrical stimuli were delivered at different knee-ankle joint configurations to explore the length-dependent property of force summation. Ultrasound images were acquired from lateral gastrocnemius and soleus muscles to allow quantification of dynamic fascicle behaviour.

Results: Force summation in the TS was less than linear over a range of muscle lengths. Greater than linear summation was observed only at short muscle lengths (plantar-flexed position) (Fig. 1). Lateral gastrocnemius and soleus fascicles experienced large amounts of shortening (13-16%) and achieved high velocities (2-3 lengths/s) in response to double pulse stimulation. The amplitude of summation in the TS was depressed and the force-frequency response dampened when a comparison was made to muscles with less fixed-end compliance.

Discussion: These findings suggest that the compliance of the Achilles tendon contributes to limiting summation and damps the force-frequency response. The Achilles tendon permits fascicle dynamics unfavourable for force production that likely offset excitation-contraction coupling processes responsible for force augmentation. A damped force-frequency response may aid accurate force production in isometric conditions (e.g. postural control). These muscles may exhibit larger degrees of force augmentation during more accustomed stretch-shortening tasks.

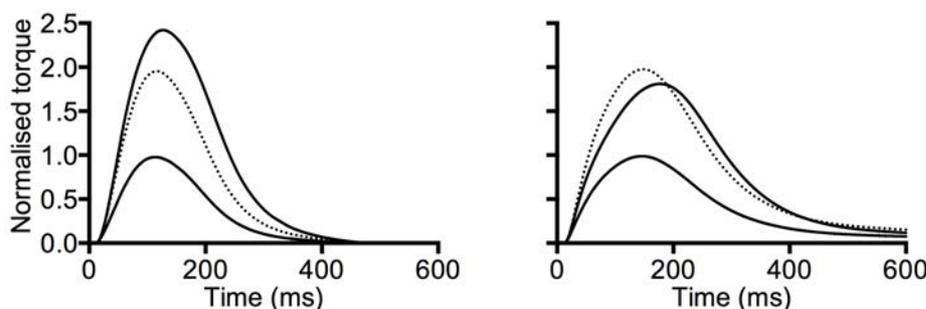


Figure 1. Waveform averaged torque summation as a function of joint position Normalised torque (relative to the maximum torque in single twitch) for the knee extended-plantar flexed (left) and -dorsiflexed (right) ankle configurations (n = 21). Double pulse responses are for an ISI (interstimulus interval) of 5 ms. Dotted lines represent linear summation of the twitch response for an ISI of 5 ms.

Movement Variability in the Gait of Parkinson's Sufferers

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Introduction:

Whilst previous research has shown that risk of falls in a PD population is linked to a greater variability in key 'outcome' measures of gait (eg, stride length, stride time), it is unclear whether those at a higher risk of falling exhibit a similar increase in variability within individual joint movements during the gait cycle. The aim of this study was to compare movement variability in the lower limb kinematics in the sagittal plane across a healthy population, PD sufferers with no history of falls and PD sufferers with a history of falls.

Methods:

Thirty participants between the ages of 50 and 70 (10 PD sufferers with a history of falls, 10 PD sufferers with no history of falls and 10 aged matched healthy participants) walked for one minute on a treadmill at their preferred speed. Retro-reflective markers on the lower limbs were tracked with a 10 camera motion analysis system, operating at 120Hz and individual joint kinematics were calculated using ISB recommendations. Variability (represented by standard deviation) in range of motion was calculated across the hip, knee and ankle for each participant and subsequently compared across groups ($\alpha < 0.05$).

Results:

PD fallers exhibited significantly greater range of motion variability at the hip and knee joints compared to both other groups. No differences in variability existed between PD non-fallers and a healthy population for any joint movement.

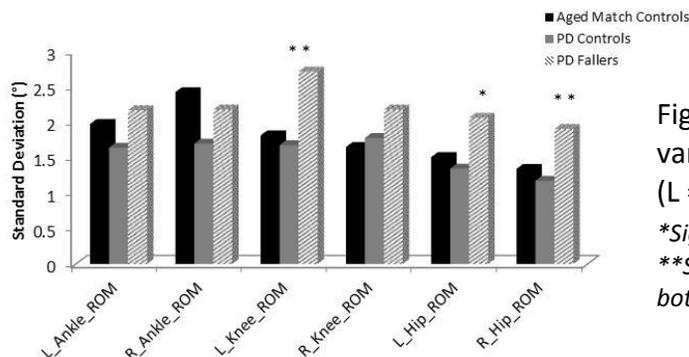


Figure: Mean range of motion variability between groups (L = left side, R = right side)
*Sig diff between PD fallers and PD controls
**Sig difference between PD fallers and both other groups

Discussion:

This study indicates that the increased gait outcome variability associated with risk of falls in a PD population is matched by an increase in movement variability at the hip and knee joints. Future research is required to investigate whether this greater movement variability is the product of a coordinative decline and/or an increase in random sensorimotor noise.

The Effects Of Unilateral Pain And Perturbation On Gait Symmetry

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Introduction: Gait asymmetry has been associated with an increase in the metabolic cost of walking and the risk of falls. Previous studies using unilateral gait perturbations have suggested that stride duration, length and symmetry may be preferentially preserved over other gait parameters during treadmill walking and that pain may limit improvements made in motor performance with subsequent exposures to the same perturbation (motor retention). This study aimed to assess how the spatiotemporal parameters of gait adapt in response to a unilateral perturbation in the presence of pain and how this impacts gait symmetry and motor retention.

Methods: Twenty-eight healthy participants were divided into two groups (n=14 Control and n=14 Pain). On Day 1, participants walked on a treadmill for 5 minutes during each of 3 conditions; before (Baseline), during (Perturbation), and after a perturbation was applied. The perturbation consisted of a length of Theraband elastic tubing attached to the subject's dominant foot, which created a forward and upward pull on the foot during swing. In the Pain group, topical capsaicin cream was applied to the dominant leg over the posterior thigh prior to the baseline session (Day 1). This induced tonic pain (>3/10) throughout the Day 1 walking tasks. On Day 2 both groups repeated the 3 walking tasks free of pain. Outcome measures included stride length, stride duration, and symmetry index (SI: see formula below). Stride length and duration were compared between Groups (Control, Pain), Epochs (Baseline, Early Perturbation Day 1, Late Perturbation Day 1, Early Perturbation Day 2, Late Perturbation Day 2), and Legs (Dominant, Non-Dominant). SI was compared between Groups and Epochs.

Results: An Epoch*Leg and Group*Epoch*Leg interaction was found for stride duration and stride length, respectively (both $p \leq 0.02$). Stride duration was longer in late perturbation than early perturbation on Day 1 for both limbs ($p < 0.001$) and on Day 2 for the unperturbed limb ($p < 0.001$). Stride duration decreased in both groups and limbs between late perturbation Day 1 and early perturbation Day 2 ($p < 0.001$). The Control group took larger strides than the Pain group during all Epochs ($p < 0.001$). Stride length for both limbs of the Control group, but only the perturbed limb in the pain group decreased between late perturbation Day 1 and early perturbation Day 2 ($p < 0.05$). A main effect for Epoch was found for both SIs. Stride duration was more asymmetrical in the early perturbation Epochs only on both days relative to baseline ($p < 0.03$) while stride length was more asymmetrical than baseline in all other epochs ($p < 0.02$).

Discussion: Stride duration, length and symmetry were not preserved during the exposure to a unilateral perturbation. Adaptations to stride patterns during the initial perturbation were not retained between exposures to the perturbation for either group. These findings differ from previous treadmill walking studies that report relatively stable stride length, duration, and symmetry during exposure to a unilateral perturbation. This may be explained by the potential difference in the energetic cost of having asymmetric stride duration compared to asymmetric step length and the magnitude of the perturbation used in this study which may have been more significant than those of previous studies.

$SI = \left| \frac{Xp - Xu}{0.5(Xp + Xu)} \right|$ where Xp and Xu represent the values for the perturbed and unperturbed limbs, respectively.

A pilot study investigating the relationship between tibialis anterior muscle fascicle dynamics and muscle spindle firing patterns.

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Muscle spindles are an important source of proprioceptive information. In human studies, spindle recordings are typically interpreted with relation to joint movement and direct measurements of muscle fibre length not monitored. Muscle fibres commonly become decoupled from joint rotations due to the compliance of elastic tissues that lie in series with the muscle. As such, the relationship between muscle fascicle dynamics and spindle firing rate cannot be directly inferred from these studies.

The primary aim of this pilot study was to describe the relationship between spindle firing patterns and muscle fascicle dynamics in the tibialis anterior muscle (TA) during passive ankle rotations. Fascicle dynamics were obtained using ultrasonography, which is a non-invasive measurement technique that can be used to visualise muscle fascicles *in vivo*. Recordings from TA muscle spindle afferents were made using a tungsten microelectrode inserted percutaneously into the common peroneal nerve. Ankle position was moved through plantar flexion and dorsiflexion in a sinusoidal pattern using varying amplitudes and velocities of rotation.

Small length changes (<1mm) were accurately measured for TA muscle fascicles, which were slightly out of phase with ankle movements. The onset of spindle firing was closely linked to the onset of muscle fascicle stretch, with peak firing rate (~8-20Hz) closely coinciding with the peak lengthening velocity. Spindle firing rate was higher during the fascicle-lengthening phase compared to the same fascicle lengths during the shortening phase.

The results confirm the ability of the TA muscle spindles to sense both fascicle length and velocity changes. The firing patterns were slightly out of phase with joint position suggesting that decoupling of the muscle from joint rotations may have implications for joint position sense. Future research should include tasks or situations where a more compliant muscle-tendon linkage exists, to further understand the implications of muscle fibre decoupling on the spindles ability to sense joint position.

Ultrasound reveals negligible co-contraction during isometric plantar flexion and dorsiflexion despite the presence of antagonist electromyographic activity

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Introduction: Because of the approximate linear relationship between muscle activity and muscle force, muscle force contributions are often estimated during maximal voluntary isometric contractions (MVICs) from surface electromyography (sEMG) and torque measurements. However, sEMG recordings from a target muscle (e.g. antagonist) may contain cross-talk originating from nearby muscles (e.g. agonists), which could lead to erroneous force estimates. Since muscle fascicle shortening and muscle force are almost linearly related when joint angle remains constant [1], ultrasonography can be used to quantify the length changes of fascicles when muscles act as agonists or antagonists during isometric contractions and therefore provides a novel way to verify whether sEMG recordings represent actual co-contraction.

Methods: Ultrasound imaging was used to measure *in vivo* muscle fascicle length (L_f) changes and sEMG to measure muscle activity of the MG, lateral gastrocnemius (LG), soleus (SOL) and tibialis anterior (TA) muscles during ramp MVICs in plantar and dorsiflexion directions. Motion capture was used to record the small ankle angle changes during the ramp MVICs and passive rotations were performed to correct L_f changes due to ankle rotation.

Results: After correcting longitudinal L_f changes for ankle rotation, the antagonist L_f at peak antagonist root-mean-square (RMS) amplitude was significantly longer than the agonist L_f at this sEMG-matched level for all muscles (Figure 1). Normalised peak antagonist sEMG RMS amplitudes were 7 to 23% MVIC across all muscles.

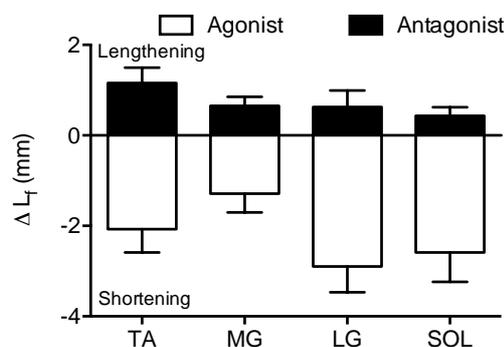


Figure 1. Longitudinal fascicle length (L_f) changes (corrected for ankle rotation) of the tibialis anterior (TA), medial gastrocnemius (MG), lateral gastrocnemius (LG) and soleus (SOL) muscles during surface electromyography root-mean-square amplitude-matched agonist (unfilled bars) and antagonist (filled bars) contractions.

Discussion: The lack of fascicle shortening when muscles acted as antagonists indicates that co-contraction was likely to be negligible, despite co-contraction as determined by sEMG of between 7 to 23% MVIC across all muscles. Consequently, investigators should be wary about performing agonist torque corrections for isometric plantar flexion and dorsiflexion based on the antagonist sEMG trace and predicted antagonist moment.

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OPTIMAL LENGTH FOR TONGUE PROTRUSION FORCE IN HUMANS

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The human tongue is a unique structure with intrinsic and extrinsic muscles in a hydrostat, its force generating capacity reflects the interaction of several muscles. Respiratory rhythm of the tongue is modulated by feedback from pulmonary stretch receptors and this has a greater inhibitory effect on the discharge of hypoglossal motoneurons compared to phrenic motoneurons. How these afferents influence voluntary activation of the human tongue is not known.

Quasi-isometric voluntary protrusion forces were measured in 15 healthy subjects; age 29.0 ± 2.4 years (mean \pm 95% confidence interval) at eight positions; protrusion to 12mm and 4mm beyond the incisors, neutral (0 mm, aligned with incisors), and retraction to -4, -12, -16, -24 and -32mm behind the incisors. Tongue protrusions were repeated at different lung volumes: functional residual capacity (FRC, day 1), total lung capacity (TLC, day 2), and residual volume (RV, day 3). The tongue position at which each subject produced the largest protrusion force at FRC was tested again at the second and third visit.

Maximal force occurred between 12mm and 32mm retraction (optimal median 16mm). Maximum force at FRC was reproducible at the optimal tongue position across 3 sessions ($P=0.68$, $ICC=0.883$). Across all positions at FRC the average force was highest at 24 mm retraction (28.3 ± 5.3 N, mean \pm 95% CI) and lowest at 12 mm protrusion ($49.1 \pm 4.6\%$ maximum; $P<0.05$). Maximal tongue force across all positions was on average 9.3% lower at FRC than TLC and RV (range: 4.5-12.7% maximum, $P<0.05$).

These results describe reproducible maximal voluntary protrusions, and our results extend previously published data to show reduced forces with protrusion beyond the incisors. Our study is the first to control for lung volume illustrating a $\sim 10\%$ increase at TLC and RV. Our results suggest that static changes in lung volume will not compromise the ability of the tongue to produce protrusion force.

Location and characteristics of stiffness change related to voluntary contraction of the urethral sphincter muscles quantified with supersonic shear imaging

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Introduction: Urinary continence is maintained if pressure inside the urethra exceeds pressure in the bladder. This seemingly simplistic mechanism requires complex coordination of a range of muscular and fascial structures, which are incompletely understood. Supersonic Shear Imaging (SSI) is an elastographic technique that quantifies the shear elastic modulus of a localised area of tissue. Stiffness measured using SSI is linearly related to muscle force [1, 2] and muscle activity [3]. SSI has not been used to study the change in stiffness of peri-urethral structures during contraction. The aims of this study were to: (i) assess the feasibility of SSI to quantify changes in stiffness of peri-urethral tissue during voluntary contraction of the pelvic floor muscles; and (ii) quantify the amplitude, location and area of the change in stiffness of the peri-urethral structures during this activation.

Methods: Ten women aged 30 to 46 years with no history of pelvic floor muscle dysfunction or neurological disease volunteered to participate in the study. SSI measures were made with the transducer placed on the perineum. Surface electromyography (EMG) electrodes were placed peri-anally to record activity of the pelvic floor muscles. Participants performed two repetitions each of 10-s contractions to reach target a 50% of the EMG amplitude recorded during a maximal voluntary contraction. Visual feedback of contraction intensity was provided. The area, amplitude and location of stiffness increase were analysed from stored SSI images using a Matlab r2011b. Data were referenced to an axis system with its origin on the posterior pole of the symphysis pubis.

Results: Maps of tissue stiffness could be recorded using SSI from peri-urethral tissue at rest and during voluntary pelvic floor muscle contractions. The region of peak stiffness was located 3.4 to 11.8 mm (median=7.0) from the symphysis pubis and ranged from 9.2 to 44.0 kPa (median=27.5). Stiffness increased over an area of 2.6-39.3 mm² (median=7.0) with a mean amplitude ranging from 2.8 to 25.9 kPa (median=20.3).

Discussion: SSI appears to be a promising and non-invasive technique to assess the function of the peri-urethral continence mechanisms. Quantitative measures obtained with the SSI provided information about a dimension of the continence mechanism that has not been studied before.

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Survey of methods for lower limb joint definitions in subject-specific models

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Introduction

Subject-specific modelling based on medical imaging has become a useful tool for research and is emerging as a useful tool for clinical decision-making. The process of creating a subject specific skeletal model involves segmentation of radiological images and definition of joint centres and axes. There is common agreement in the literature that the hip joint centre can be found by fitting a sphere to the femoral head. For the knee and ankle joint definition, however, slightly different approaches have been described. The purpose of this study was to find the most reliable methods to estimate lower limb joint centres and axes from medical images.

Methods

Lower limb magnetic resonance images of five children with cerebral palsy were collected at the Royal Children's Hospital (Brisbane, Australia). Three investigators (HK, HH, LR-J) segmented all necessary bony structure to define lower limb joint centres and axes on two occasions using Mimics and 3-matics (Materialise, Leuven, Belgium). Intra- and inter-tester reliability for five different methods to estimate the knee joint centre and three different methods to estimate the ankle joint centre were calculated.

Results and Discussion

For the knee and ankle joint definitions the most reliable methods were based on fitting spheres to the medial and lateral femoral condyles and to the medial and lateral half of the trochlea respectively (Table 1). The results from this study clarified which method should be used to ensure reliable joint definitions in subject-specific models based on medical images.

Table 1. Average (standard deviation) differences in joint localization based on different methods.

Joint	Method	Intra-tester [mm]	Inter-tester [mm]
Hip	Fitting a sphere to the femoral head. The HJC is assumed to be the centre of the sphere.	0.49 (0.32)	0.27 (0.26)
Knee	Fitting spheres to the medial and lateral condyles. The KJC is assumed to be the midpoint between the centre of both spheres	2.84 (0.58)	2.76 (1.76)
	Fitting ellipsoids to the medial and lateral condyles. The KJC is assumed to be the midpoint between the centre of both ellipsoids	2.73 (2.26)	2.86 (3.69)
	Fitting ellipses to the outer boundary of the medial and lateral condyles. KJC is assumed to be the midpoint between the centres of both ellipses.	3.18 (1.87)	4.46 (2.41)
	Selecting the most medial and lateral point on both condyles. The KJC is assumed to be the midpoint between both points.	6.42 (0.36)	3.49 (2.05)
	Select the most anterior point in the middle of the fossa intercondylaris.	4.83 (5.95)	3.15 (3.39)
Ankle	Fitting spheres to the medial and lateral half of the trochlea. The AJC is assumed to be the midpoint between the centres of both spheres.	1.85 (1.40)	1.43 (1.62)
	Fitting a sphere to the bottom surface of the tibiofibulotalar joint space.	2.46 (0.93)	1.67 (0.25)
	Selecting the most medial and lateral point on both malleoli. The AJC is assumed to be the midpoint between both points.	3.11 (1.72)	5.46 (2.96)

How fast can we really move our legs?

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Introduction: Human performances produced during sprint exercises are very sensitive to variations in movement velocity/frequency. It is well established that humans can only produce maximal levels of power at optimal movement velocities/frequencies. During sprint cycling exercises, the optimal pedalling cadence (C_{opt}) for power production is usually comprised between 110 and 130 rotations per minute (rpm) for most humans. Numerous studies predicted that the maximal pedalling cadence (C_{max}) that a subject can reach (while sprinting against no resistance) would be twice C_{opt} . However, C_{max} values may have been overestimated as controlling the kinematics of the lower limbs and maximally activating/deactivating the lower limb muscles seriously challenges the central nervous system when pedalling at high cadences. The aims of this study were 1) to determine if C_{max} actually equals twice C_{opt} and 2) to describe the changes in lower limb kinematics and muscle activation observed from C_{opt} to C_{max} .

Methods: Twelve physically active males performed a torque-velocity test and a maximal sprint against no external resistance on a stationary cycle ergometer fitted with instrumented cranks. We measured the range of motion (ROM) and angular velocities of the three lower limb joints (ankle, knee and hip) from a 3D kinematics analysis. We also calculated normalized peakEMG, minEMG and activation duration (in % of pedalling cycle duration) of six muscles [*gluteus maximus* (GMAX), *rectus femoris* (RF), *vastus lateralis* (VAS), *semitendinosus* and *biceps femoris* (HAM), *medial gastrocnemius* (GAS), *tibialis anterior* (TA)]. EMG and kinematic variables were obtained from a series of 3 pedalling cycles completed by participants at C_{opt} and C_{max} . Two-way ANOVAs with repeated measures were performed to analyse the effect of cadence and joint (kinematic variables)/muscle (EMG variables).

Results: Participants' C_{max} was 218 ± 17 rpm and C_{opt} 124 ± 8 rpm. C_{max} was lower than twice C_{opt} (-31 ± 21 rpm, $P < 0.05$) and no correlation was observed between the two cadences ($r = 0.18$, $P = 0.58$). The increase in joint angular velocities measured from C_{opt} to C_{max} was lowest for the ankle ($106 \pm 129^\circ/s$). Knee ($-8 \pm 8^\circ$) and ankle ($-5 \pm 7^\circ$) ROM decreased from C_{opt} to C_{max} ($P < 0.05$). A reduction in peakEMG ($-14 \pm 9\%$, $P < 0.05$), an increase in minEMG ($+2 \pm 3\%$, $P < 0.05$) and an increase in activation duration ($+11 \pm 10\%$, $P < 0.05$) of the lower limb muscles was observed between C_{opt} and C_{max} .

Discussion: Subjects reached maximal cadences that were $12 \pm 8\%$ lower compared to those predicted by previous studies. At maximal cadences, we observed a change in the control strategy of the pedalling movement that consisted in reducing the ROM of the knee and ankle joints. In parallel, the EMG results revealed that the maximal level of activation of the lower limb muscles was reduced at C_{max} , while the level and duration of relaxation of the lower limb muscles was increased when cycling at maximal cadence. To conclude, the maximal pedalling movement velocities/frequencies of humans seem to be limited by motor control strategies and activation-deactivation dynamics of the lower limb muscles.

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

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Introduction: Timing is crucial for effective motor control. Time intervals can be represented relative to a recurrent beat (beat-based timing), or by representing absolute durations (nonbeat-based timing) (Grahn & Brett, 2007; Teki et al., 2011). Neuroimaging and neuropsychological work suggests involvement of the supplementary motor area (SMA), the premotor cortices and the cerebellum in beat and nonbeat-based timing (Kung et al., 2013; Grahn & Rowe, 2013; Geiser et al., 2013). **Methods:** Here, we alter beat-based and nonbeat-based timing by modulating excitability of the supplementary motor area (SMA), the right cerebellum and the bilateral dorsal premotor cortices, using 2mA transcranial direct current stimulation. Subjects discriminated beat rhythms which elicit beat-based timing, and nonbeat rhythms which do not elicit beat-based timing. **Results:** Discrimination of beat rhythms was improved by increasing SMA excitability, and impaired by decreasing SMA excitability. This effect was not evident when modulating excitability of the premotor cortex. Both increasing and decreasing excitability of the cerebellum impaired discrimination of both beat and non-beat rhythms, possibly by impairing working memory. **Discussion:** These results suggest that beat-based timing is primarily subserved by the SMA, not the premotor cortex, nor the cerebellum.

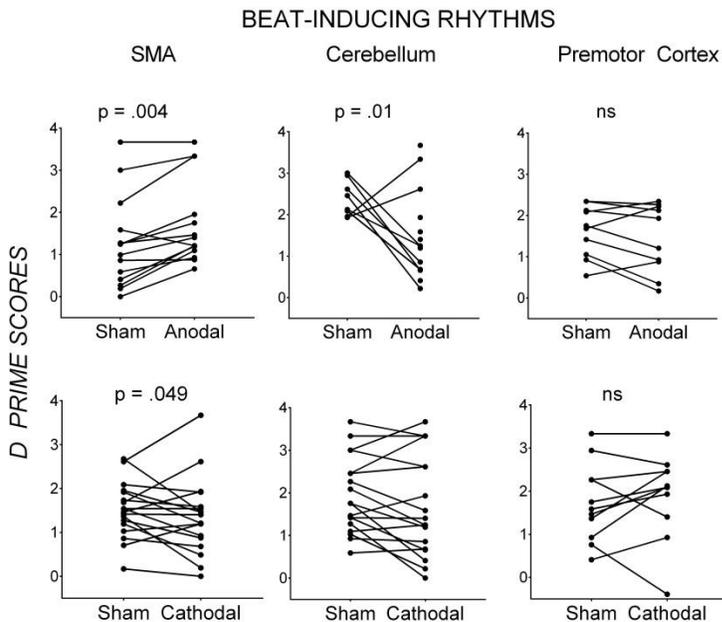


Figure 1. Transcranial direct current stimulation of the SMA, and not the cerebellum, nor the premotor cortex, alters discrimination performance of beat-inducing rhythms in a polarity-dependent fashion.

Reaction time and anticipatory skill of athletes in open and closed skill-dominated sport

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Introduction: In sports, reaction time and anticipatory skill are critical aspects of perceptual abilities. To date, no study has compared reaction time and anticipatory skill of athletes from open and closed skill-dominated sport. Accordingly, the present study investigated whether a difference exists in sensory-cognitive skills between these two different sport domains.

Methods: Eleven volleyball players and 11 sprinters participated in this experiment. Reaction time and anticipatory skill of both groups were recorded by a custom-made software called SART (speed anticipation and reaction time test). This software consists of six sensory-cognitive tests that evaluate visual choice reaction time, visual complex choice reaction time, auditory choice reaction time, auditory complex choice reaction time, and anticipatory skill of the high speed and low speed of the ball. For each variable, an independent *t*-test was performed.

Results: Results suggested that sprinters were better in both auditory reaction times ($P < 0.001$ for both tests) and volleyball players were better in both anticipatory skill tests ($P = 0.007$ and $P = 0.04$ for anticipatory skill of the high speed and low speed of the ball, respectively). However, no significant differences were found in both visual choice reaction time tests ($P > 0.05$ for both visual reaction time tests).

Discussion and conclusion: It is concluded that athletes have greater sensory-cognitive skills related to their specific sport domain either open or closed.

Sensory basis of limb position sense differs between pointing and matching

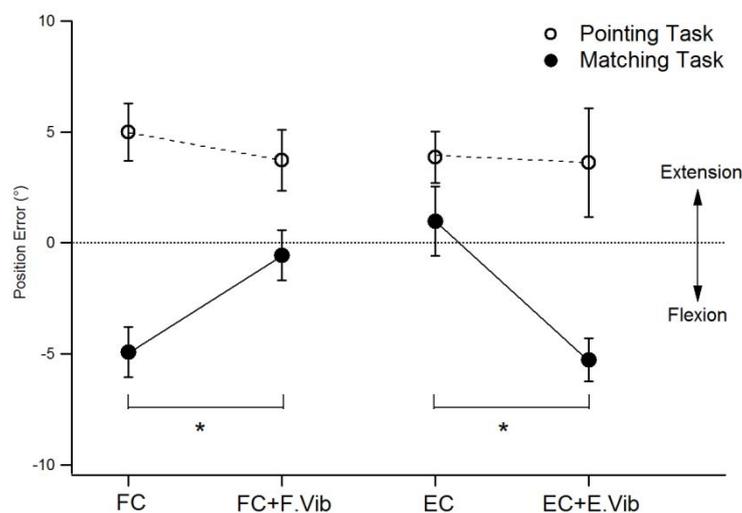
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Introduction: Historically, evidence that muscle spindle signals contribute to our sense of limb position comes from studies where muscle vibration elicits an illusion of lengthening of the vibrated muscle. We have re-examined the vibration illusion under two different experimental conditions. In one the position of the unseen limb is indicated by placement of the contralateral limb, in the other its position is indicated by pointing. The results suggest that inputs from muscle spindles play a dominant role in limb matching but that this dominance is not apparent in limb pointing.

Method: Ten healthy subjects (3 male, 7 female, mean age 24.0 ± 1.6 yrs) were recruited for the study. They were instructed to indicate the position of their unseen, *reference* arm by either 'matching' it with their contralateral arm, *indicator* (done blindfolded), or show its position with a 'pointer.' The subject isometrically contracted either their elbow flexors in flexed position (FC) or extensors in extended position (EC) at approximately 50% maximal effort, before each trial. In another condition, vibration over the belly of the biceps brachii and triceps brachii was applied at 70 Hz for ten seconds before subjects declared the position of their unseen arm. The elbow-joint angle was measured to calculate the position error: $position\ error(^{\circ}) = reference(^{\circ}) - indicator(^{\circ})$. A repeated measures ANOVA, followed by LSD post-hoc, was used to identify statistical significance ($p < 0.05$).

Results: The figure shows that in the matching task vibration of flexors or extensors of the reference arm caused a significant shift in position of the arm towards extension or flexion respectively, as shown by placement of the indicator arm. No significant shift was observed during vibration in the pointing task.



Discussion: The data suggests that the sensory basis of limb position sense as measured in a matching task is different from that in a pointing task. Matching involves signals of muscle spindles, whereas in pointing there is a change in the receptor basis of the sense.

Changes in the inspiratory loading reflex during postural activation of scalenes in humans.

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Introduction: Inspiratory loading during brief airway occlusion produces a short-latency reflex inhibition in scalenes. Increasing the chemical drive to breathe with hypercapnia at matched levels of muscle activity does not alter this inhibitory loading reflex (Murray et al., 2010). This aim of this study was to determine the effect on the short-latency reflex inhibition when the background motor discharge in scalenes is increased with postural or inspiratory drive.

Methods: Electromyograms (EMG) were recorded bilaterally from scalenes and sternocleidomastoid (SCM) with surface electrodes. Subjects were screened for phasic respiratory activity in scalenes EMG during eupnoea, with 11 of 16 subjects included in our study. With subjects seated, the inspiratory muscles were loaded by occluding airflow during eupnoea with the head and neck relaxed and supported by a pillow or with the head actively held in the same posture with neck flexion. Brief airway occlusions, 120 per condition at an average frequency of 1 in 3 breaths, were delivered during inspiration at a volume threshold of ~0.2 L. On different days, inspiratory loading was also performed on 8 of 11 subjects during normocapnic voluntary hyperpnoea with the volume threshold set to produce a similar increase in right scalenes EMG as the postural task. EMGs were rectified and then averaged for each condition.

Results: During eupnoea with the head supported, inspiratory loading produced a reflex inhibition in both scalenes EMG for all subjects, with inhibition of right SCM in 2 subjects. Neck flexion increased scalene EMG by 4.0 ± 0.7 [mean \pm 95% CI] times on the right and 3.8 ± 0.8 on the left side; however, the area of the inhibitory response to loading increased by 2.5 ± 1.4 times and 2.0 ± 0.9 times, respectively, when compared to the head-supported condition. No inhibitory response to loading was observed in SCM with neck flexion. Voluntary hyperpnoea increased right scalenes EMG by 3.4 ± 0.8 times compared to eupnoea at the onset of airway occlusion, and the area of the inhibitory response was 3.1 ± 1.6 times larger than during eupnoea. Voluntary hyperpnoea also increased activity in right SCM, with an inhibitory response to loading observed in this muscle in 4 subjects.

Conclusions: The size of this reflex response in scalenes was ~0.53 when muscle activity was increased with postural activation and 0.91 when increased through respiratory drive for the same group of subjects, which suggests the inhibitory loading reflex does not scale proportionately to an overall increase in background muscle activity.

Murray et al. 2010. J Appl Physiol 109: 87–94.

With sudden axial perturbation, posture is maintained by a rapid response, which is mediated by body weight.

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Introduction: Sudden application of load has been used to study trunk stiffness in the sagittal and coronal planes. How the body reacts to sudden axial loading has not been studied, but is relevant for many functional tasks. This study aimed to investigate how load is transmitted through the body with axial loading, and how system stiffness is modulated in response to this loading,

Methods: Loads of 20% of body weight were held with light contact onto the shoulders, and then released unexpectedly to generate axial loads in twenty-two healthy participants (10 males). Force transducers at each shoulder measured input force, and a forceplate below the participant measured output force. Analyses involved calculation of system stiffness at the time of peak load displacement (catch-phase), and peak force output (response-phase).

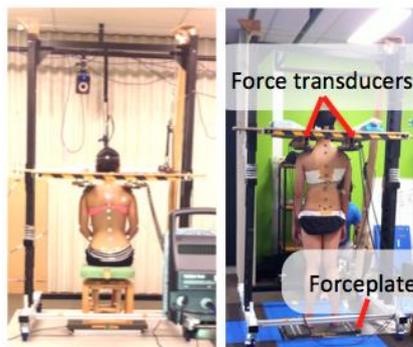


Figure 1. Exemplar trial data for force input and output

Results: Mean (SD) system stiffness at peak force output was 16.4 (3.8) N/mm at 116 (10) ms after the onset of load input in sitting, and 17.2 (4.8) N/mm at 107 (8) ms in standing. Key discoveries with axial load perturbation were that

- The peak force output exceeded the peak force input by 44.8 (10.0) % in sitting, and by 30.4 (7.9) % in standing.
- Greater body weight was associated with greater stiffness (simple linear regression, weight: $F(1,20)=21.6$, $P<0.001$ in sitting; and $F(1,20)=21.4$, $P<0.001$ in standing).

Discussion: Despite the greater motion segments in standing than sitting, these data demonstrate remarkably similar properties when the body is perturbed by axial load in either posture. Future studies will use electromyography recordings to understand the contribution of neuromuscular responses to the measured mechanical properties that maintain upright posture against axial load perturbation. The relationship between body weight and stiffness implies future studies that compare properties between cohorts must control for body weight.

Does Perception of Time Alter Under Hypnosis?

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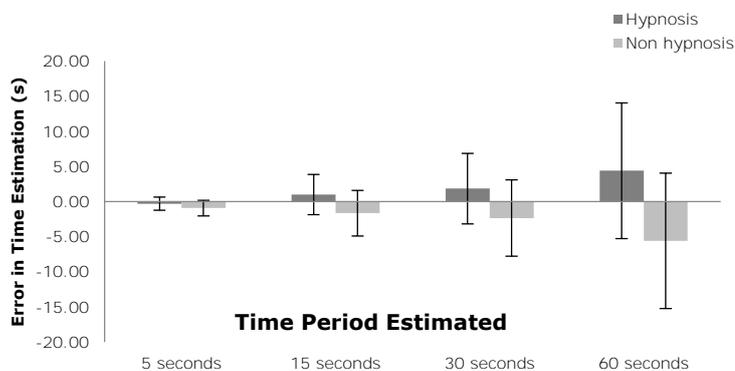
Introduction: The aim of this study was to test the hypothesis that hypnosis distorts the brain's capability to accurately estimate a fixed duration. Previous research was equivocal – some reports suggested duration would be over-estimated under hypnosis. Typically non-hypnotised participants underestimate a fixed duration and the underestimation increases at longer durations.

Methods:

Ten (6 female) participants aged 19-24y were assessed for hypnotic susceptibility (Stanford Hypnotic Susceptibility Scale) prior to undertaking a time estimation task, under and without hypnosis. Half the participants performed the task under hypnosis first. After practice, each task required estimation of the duration of 5, 15, 30 and 60 second periods presented in a pseudo-random order. For each interval the participant, using a stopwatch (facedown) activated the start button to begin the trial and pressed the stop button when they estimated the duration to have ended.

Results: Data for one participant were excluded because of an equipment failure during the experiment. As illustrated, errors (M, SD) in time estimation

Prospective Time Estimations: With and Without Hypnosis



increased as the duration lengthened. As predicted, without hypnosis underestimation was greater at longer durations. Under hypnosis, the opposite effect occurred – overestimation increased at longer intervals.

Discussion: Under hypnosis prospective time estimation results in an overestimation of the length of the interval being judged. Participants assessed as less susceptible to hypnotic suggestion demonstrated less distortion of time estimation. This result suggests that the influence of hypnosis on prospective time estimation and thus on brain activity is affected at least in part by an **individual's susceptibility** to hypnotic suggestion, potentially a trait effect that may interact with the hypnotic process.