POSTER SESSION I:

Theme I: Cortical and Spinal Mechanisms of Motor Control

Poster #7

Effects of motor cortical stimulation during planar and 3D reaching movements

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ABSTRACT

Reaching movements are part of many activities of daily living and are thus a common target of rehabilitation-related research. These movements occur in 3D, although physiological investigations often employ 2D reaches for the sake of simplicity. We first investigated whether single pulse transcranial magnetic stimulation (TMS) over primary motor cortex could have useful or disruptive effects when delivered at different times during a center-out reaching task in a 2D rehabilitation robot. TMS at 120% of the movement threshold was delivered at rest and when subjects performed a series of reaching tasks. The 5 different conditions were: no stimulation, sham stimulation, and stimulation at 150, 500, or 1000 ms after the go cue. When TMS was applied at 150 ms, the evoked path lengths were significantly shorter than at rest and had less deviation than the no-stimulation condition ($p < 0.05$). Peak velocities were lowest during the no-stimulation condition and highest during the 500ms condition ($p < 0.05$). Path lengths were significantly shorter during the no-stimulation, sham, and 150ms condition compared to the 500ms and 1000ms conditions. Conclusions: TMS applied prior to movement onset suppressed movements evoked by TMS, decreased trajectory deviations, and shortened path length, while TMS delivered after movement onset increased PV and path length. Follow-up study: We are investigating the effects of double-pulse stimulation over multiple cortical motor areas on 3D reaches. Our hypotheses include a prediction that anti-gravity motor output will be localized more in SMA and occur with shorter reaction time than planar output, which will also localize to the premotor cortex. This will provide complementary information about the role of multiple cortical areas and the potentially augmenting effects of cortical stimulation in neurorehabilitation.

Poster #12

The maintenance of attention during two concurrent motor tasks: Preliminary findings using transcranial magnetic stimulation

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ABSTRACT

Dual task (DT) research has shown that when an individual performs two motor tasks simultaneously there is increased, or decreased, corticomotor activity compared to single task (ST) performance alone. These variations in results may be due to the prioritization of one task over another during DT activity. The aim of this study was to use TMS to investigate corticospinal activity in response to a dual motor task where attention was maintained during both tasks. Using a counterbalanced, cross-over design, healthy males (n=5; aged 32±10.6 years) completed, in randomized order, 4 conditions: ST easy (pincer grip of 15% of maximal voluntary contraction [MVC]±5%); ST difficult (15% MVC±1%); DT easy (pincer grip 15% MVC±5% during cycling at 10 revolutions per minute [rpm]); and DT difficult (pincer grip 15% MVC±1% during cycling at 10 rpm). During all conditions, feedback was given equally for both riding speed and contraction force via a computer screen. TMS was delivered at 20% of the stimulator output above active motor threshold. Twelve pulses were delivered, in sets of 3, spaced at random intervals of 5-8 s apart, with 1 min rest between each set. Comparisons of grouped DT to ST conditions showed a 12.2% increase in MEP amplitude. The DT difficult condition showed a 27.2% increase in MEP amplitude compared to the ST easy (Cohen's *d* 0.6) and 17.5% increase compared to the ST difficult (*d* 0.4) conditions. In addition, the DT difficult condition demonstrated a 5.9% and 4.5% decrease in silent period duration in comparison to the ST easy (*d* 0.4) and ST difficult condition (*d* 0.3) respectively. This preliminary study has shown that performing two motor tasks, where attention is maintained to both concurrently, results in higher corticospinal excitability compared to a ST alone. In addition, a further increase in attentional requirements via greater DT difficulty demonstrates enhanced corticospinal excitability again.

Poster #13

Timing dependant effects of tDCS on ankle motor skill acquisition

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ABSTRACT

Transcranial direct current stimulation (tDCS) has emerged as a promising tool to induce changes in cortical excitability and improve functional outcomes. Understanding the interaction between tDCS and motor function is important for developing rehabilitation approaches. The effects of tDCS may depend on the timing with which it is applied relative to physical training interventions. To the best of our knowledge, no previous study has compared responses with an ankle motor control task performed before and during tDCS. We conducted a single blinded, randomized, sham controlled cross over trial. We recruited 11 right handed healthy participants to practice in a visuomotor tracking task performed with their non-dominant ankle for 15 minutes while receiving 1 mA of facilitatory anodal tDCS to the motor cortex (M1) for 15 mins. Subjects received 3 interventions in a randomized order separated by a week: a) tDCS before motor practice, b) tDCS during motor practice and c) sham stimulation during motor practice. Cortical excitability was measured at baseline and post training. Tracking accuracy of the ankle, calculated as an accuracy index, was measured pre, post and 24 hours after training. A repeated measure ANOVA showed significant group differences for MEP amplitude and accuracy index. Post hoc analyses showed that post MEP amplitude was significantly increased for tDCS-during compared to tDCS-rest or sham ($p < 0.05$). Tracking accuracy at post and 24hrs after training was significantly higher for the tDCS-REST condition compared to others ($p=0.05$). In summary our results showed that application of tDCS prior to performance of the ankle skill learning task led to greater improvements in practice and retention. We also found a dissociation between corticospinal excitability measures and motor outcomes. Future studies will further examine the timing dependant differences in plasticity and function of non-invasive brain stimulation.

Poster #16

Non-selective change in short-latency afferent inhibition during movement preparation

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ABSTRACT

Somatosensory input inhibits primary motor cortex (M1) output at approximately 20-25ms following peripheral nerve stimulation, an effect known as short-latency afferent inhibition (SAI). SAI occurs at rest, but is reduced while preparing and executing movement. It is unknown whether reduced SAI during movement preparation is specific to the muscle involved in the task compared to a muscle not involved. The purpose of this study was to determine how SAI is modulated during movement preparation in a simple reaction time task involving either 2^{nd} or 5^{th} digit movement. It was hypothesized that SAI would be reduced for the muscle when it is involved in the task, but SAI would be unchanged when it is not involved. Participants were required to perform the reaction time task in the presence of a "warning" and "go" cue. The nature of the warning cue determined the upcoming movement; one tone would indicate 2^{nd} digit flexion, while two tones would indicate 5^{th} digit flexion. A transcranial magnetic stimulation (TMS) pulse was delivered alone over M1 "hotspot" for the first dorsal interosseous (FDI) muscle of the right hand and motor evoked potentials were recorded (unconditioned MEP). To test for SAI, the cutaneous nerve of the index finger was stimulated 25 ms before the single TMS pulse and the resultant MEP was recorded in FDI (conditioned MEP). 16 unconditioned and 16 conditioned MEPs were obtained either at rest or one second after the warning cue when the participant was preparing to perform 2^{nd} digit or 5^{th} digit movement. Preliminary data (n = 5) suggests that during movement preparation somatic inputs cause a change in M1 from inhibition to facilitation regardless of whether the 2^{nd} or 5^{th} digit is about to perform the task. These data could indicate that the relevancy of the somatic inputs to the task may not be driving the changes in M1 excitability during movement preparation and instead the changes are non-selective to the digit involved.

Poster #22

Corticomotor responses during dual task performance: A systematic review of the literature from 1995-2012

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ABSTRACT

This systematic review was conducted firstly to identify the extent and nature of dual task (DT) research using neuroimaging and movement tasks, and secondly to quantify DT vs. single task corticomotor responses within this research. A systematic literature search was performed targeting research that has used a DT paradigm involving at least one motor task, and a neuroimaging method to assess corticomotor activity. Healthy humans over the age of 18 were targeted as participants for assessment. In each database, searches were limited to peer- reviewed, full text publications printed in English between 1995-2012, using combinations of the search terms 'dual task*', 'concurrent*', and 'motor cort*'. Articles were initially screened for title and abstract, with the full texts then obtained for quality assessment and data extraction. Studies were considered for an initial review if they used a neuroimaging method to assess a DT involving physical movement, while a detailed analysis was performed on studies that also involved at least one motor task (as defined within the review) within their DT, and assessed the activity of motor areas with neuroimaging. From an initial yield of 1293 articles, thirty-five articles met the criteria for an initial analysis, and ten articles for a detailed analysis. 26 of 35 DT studies used movement of only the fingers or hands, and corticomotor responses were unchanged in the majority of dual versus single task tests. A small amount of studies (n= 2) demonstrated decreased corticomotor activity DT vs. ST when attention was distracted by the performance of the secondary task, however there were not enough studies of this nature to confirm this trend. There is little consensus regarding typical corticomotor responses during dual motor tasking. Future DT research should focus more heavily on neurophysiological responses during relevant, gross movements.

Poster #23

Brain anatomical correlates of auditory-motor synchronization in children with autism spectrum disorder

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ABSTRACT

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder that is characterized by impaired social interaction and communication, as well as atypical sensory perception. Individuals with ASD generally have diminished processing of complex, verbal and social material (e.g. speech), but can have enhanced processing of basic, non-verbal and non-social material (e.g. music). (Ouimet et al., 2012) Auditory-motor synchronization is critical to both speech and music, but has not been studied much in ASD. Here, we investigated basic auditory-motor synchronization in ASD children and how performance maps onto brain structure. We studied 37 children with ASD and 44 TD age-matched controls (mean age across groups: 11.7, SD: 2.8, range: 6-16 years). Participants were tested on an auditory-motor synchronization task in which they tapped in synchrony with auditory rhythms of varying metrical complexity. (Chen et al., 2008) Performance was calculated in terms of the participant's ability to reproduce time intervals between each sound event in a sequence. T1-weighted brain anatomical MR images were acquired for all subjects and cortical thickness maps were generated. Statistical analyses were performed at every point on the cortical mantle to test for significant correlations between cortical thickness and performance on the auditory-motor task. All children (both ASD and TD) performed worse on more complex rhythms, but children with ASD showed better performance on the most complex rhythms. Cortical thickness in bilateral motor areas was positively correlated with better performance on the most complex rhythms (Fig. 1). These findings are consistent with current models of enhanced processing of basic, non-verbal and non-social stimuli in ASD. (Mottron et al., 2006)

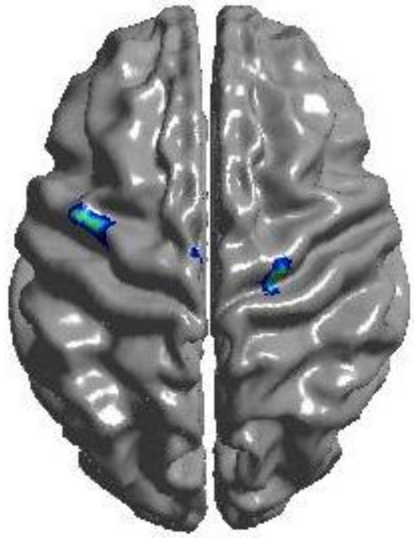

Figure 1. Auditory-motor synchronization is related to cortical thickness in bilateral motor cortex.

Poster #24

The neurophysiology of central and peripheral fatigue during sub-maximal lower limb isometric contractions

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ABSTRACT

Fatigue has been defined as an exercise-induced decline in force generation capacity. Fatigue may arise because of changes at both the peripheral and central levels. Movement is preceded and accompanied by brain activities related to the preparation and execution of movement (movement related cortical potentials, MRCPs), which have recently been correlated with the perception of effort (RPE). We combined force measurements, surface electromyography (sEMG), peripheral electrical stimulation (maximal twitch, MT) and MRCP analysis to further our understanding of the neural correlates of peripheral and central changes during a fatiguing task involving the lower limbs. Eighteen healthy volunteers performed 4 blocks of isometric knee extensions at 40% of the maximal voluntary contraction (MVC) for a total of 240 2-s contractions. At the beginning of the session and after each block, we measured RPE, MT and MVC. We simultaneously recorded the force of the knee extensor muscles, sEMG of the vastus lateralis muscle and electroencephalography (EEG) from 64 channels. The root mean square (RMS) of the sEMG was obtained. The MRCPs were extracted from the EEG recordings and averaged in the early (block 1-2) and late (block 3-4) stages of fatigue. Two cohorts were obtained by cluster analysis that was based on the RPE, which reflects the perception of effort, and MT, which is related to peripheral fatigue. We observed a significant decline in both the MVC (-13%) and RMS (-25%) of the sEMG signal over the course of the fatiguing task, suggesting that significant muscle fatigue had occurred in all of the participants regardless of the cohort. The MRCP amplitude was larger in the fatigued MT cohort compared to the non-fatigued MT cohort in the supplementary and premotor areas, whereas the MRCP amplitude was larger in the fatigued RPE cohort compared to the non-fatigued RPE cohort in the supplementary and premotor areas and in the primary motor cortex and prefrontal areas. The increase in the positive activity of the prefrontal cortex, along with the perception of effort, represents a novel result. Present findings suggest that the activity of this region of the brain, which is responsible for cognitive processing and motor planning, is modulated more by the perception of effort than peripheral fatigue. The findings from this study provide also useful information to develop appropriate intervention treatments for clinicians.

Poster #34

Increased iron content in the basal ganglia is associated with grasp-force matching

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ABSTRACT

Increased brain iron content has been linked to neural degeneration and to decline of cognitive-motor functions in healthy, older adults. The basal ganglia, which are rich in iron deposits, play an important role in hand grasp, especially in establishing and modulating force requirements to meet specific task demands. However, it is unclear if increased iron content in the basal ganglia contributes to declines in hand grasp tasks in older individuals. Twenty-five older, right-handed women participated in the present study. Each participant generated a 20% maximum voluntary exertion reference force that was matched with the opposite hand in the Contralateral Remembered (CR) and Contralateral Concurrent (CC) conditions and with the same hand in the Ipsilateral Remembered (IR) condition. T2* relaxation times were calculated from Susceptibility-Weighted MRI scans to determine iron concentration in the caudate nucleus (Cd), globus pallidus (GP), and putamen (Pt). Increased iron content in the GP, Cd and Pt was associated with relatively greater number of errors when matching force with the opposite hand in the CR and CC conditions than with the same hand in the IR condition. It is suggested that increased iron content disrupted the planning phase of force production that was more pronounced with the added demand of matching with the opposite than same hand. Increased iron content in the basal ganglia may contribute to sensorimotor declines in healthy, older women. Relative iron content quantified by non-invasive methods may be a promising biomarker of age-related motor declines.

Poster #41

Can you feel it? Sensation recognition and corticospinal excitability responses to low-level transcranial direct current stimulation

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ABSTRACT

This study investigated the ability of people to discriminate the localized sensation between three levels of transcranial direct current stimulation (tDCS): 0.5 mA, 0.8 mA and sham. A secondary aim was to measure the corticospinal responses using transcranial magnetic stimulation (TMS) at intervals up to 40 min post tDCS. Using a double blind, randomized, counterbalanced, cross over design, 9 healthy participants (4f, 5 m; 26.4±4.4years) completed 3 sessions of 20 min of constant anodal-tDCS with a 1-wk washout period between sessions. An independent person administered the tDCS using 2x25 cm2 electrodes, with the anodal electrode placed over the optimal motor area projecting to the participants' right abductor pollicis brevis muscle, identified via TMS, and the cathodal electrode placed over the contralateral supra-orbital area. During tDCS, participants recorded their perceptions of sensation using the Galer Pain Scale prior to tDCS, and at 1 min, 10 min and completion of tDCS. TMS at 20% above active motor threshold was delivered prior to tDCS, and at 5, 10, 15, 20, 30 and 40 min after tDCS whilst participants held a light tonic contraction. Mean MEP at 0.8 mA progressively increased peaking at 80% above pre-values at 15 min. MEP amplitude did not change at any time points with 0.5 mA and sham. SP duration did not change at any time points between conditions. Further, there was no difference in perception of sensation across pain and sensation subscales at any time points between conditions. This study has demonstrated, in healthy people, that tDCS increases corticospinal excitability at 0.8 mA but the level of simulation cannot be identified. The findings from this study will be progressed towards using tDCS in people with chronic hypersensitivity to painful stimuli.

Poster #43

Age-related changes in motor learning due to altered adaptive processes in the elderly

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ABSTRACT

Motor learning is often studied by examining how people adapt their motor output when moving grasped objects with novel dynamics. Such adaptation involves a fast process that adapts and decays quickly and a slower process that adapts and decays more gradually. The fast process is thought to involve declarative memory whereas the slow process is linked to implicit or procedural memory. Here we compared younger (18-34, M = 22 years old) and older adults' (56-77, M = 66 years old) adaptation to a viscous-curl force field to test the prediction that the fast process is altered in aging. We show that adaptation in both groups involves both a fast and a slow process, and that aging alters the fast process while the slow process remains intact. Specifically, we find that the fast system is slowed down in the elderly such that the rates of learning and decay are reduced compared to younger adults. These results are consistent with evidence that explicit or declarative learning mechanisms are diminished in healthy elderly individuals and provide strong support for the idea that related mechanisms underlie the fast learning process in motor adaptation.

Poster #71

Motor learning in young and elderly: influence of mental practice, observation of movement and cognition

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ABSTRACT

The learning of motor skills involves the acquisition and consolidation of a sequence of movements. The aging, among other things, causes a change in motor behavior experienced throughout life. The objective of this research is investigate the effects of observation of the movement and mental practice on motor learning, as well as the influence of cognition in learning and motor control in young and elderly. The groups consisted of 43 elderly (73.97 ± 5.67 years) and 45 young subjects (22.28 ± 3.38 years). The instruments used were: Mini-Mental State Examination (composed by an evaluation of cognition) and Digital Motor Task (DMT; composed by a training of a sequence of digital movements, an interval and a test phase). The subjects were divided into three subgroups: control, mental practice and observation of movement; the latter two were oriented to do the specific activities during the interval between training and test of DMT. This research was approved by Ethics Committee (protocol 101/557-2012). To compare the performance of different subgroups we used one-way ANOVA followed by Bonferroni's *post hoc*; to assess the relationship between motor performance and cognitive function we used Sperman's Correlation. There was no difference in performance of DMT between control, mental practice and observation subgroups in young or aged groups; however, there were differences between young and elderly subjects ($P<0.01$) performance. In young subjects, there was no correlation between cognitive function and motor performance; on the other hand, in elderly, we observed a moderate negative correlation between cognitive performance and test runtime ($r= -0.490$), and between cognitive performance and number of execution errors in the test ($r= -0.468$). Our results suggest that the mental practice and the observation of movement do not alter the motor memory in young and elderly, at least when the interval between learning and performance is brief. They also suggest that there is a significant relationship between cognitive function and learning and execution of new motor skills in elderly. This knowledge is important for elderly to adapt to the aging body and the environment in which he lives, beyond reflect markedly in the degree of autonomy/independence of these individuals.

Poster #81

Age-related differences in beta electroencephalographic changes during threshold of perception of ankle passive motion assessment

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ABSTRACT

Event-related desynchronization and synchronization (ERD/ERS) in the beta band (13-35 Hz) has been related to passive movements. Threshold of perception of passive motion is a way to assess the proprioceptive system and studies have shown increased response times (RT) in older adults. Electrophysiological correlates of ankle passive movement are still unknown in older adults, so the aim of the present study is to investigate the EEG beta band oscillatory changes during slow passive movement in a group of healthy older individuals compared to a young group. Nineteen older (70.3±4.1 years) (OA) and 19 young adults (28.5±2.9 years) (YA) were submitted to the threshold of perception of passive motion assessment. Participants were instructed to respond by pressing a button with their right thumbs as fast as possible whenever a dorsiflexion movement of the ankle was detected. Passive movement was performed at random starting times (at intervals between 3 and 7 seconds) at velocity of 0,5 º/s. EEG epochs were aligned with ankle movement onset and we analyzed, for both groups, the grand average and also divided all the trials into fast-, medium- and slow-RT trials and averaged the data. The criterion for the classification as medium-RT was to be within the median value ±½ standard deviation of the individual RT. The results showed an increased RT in the OA group (2112.01±268.18ms) compared to the YA group (1262.43±420.70ms) and a delayed beta ERD for OA. Beta ERS following the beta ERD was present only for the OA. Data analyzed separately according to RT showed that ERD and ERS (for OA) latency was delayed when the RT was slow. We conclude that age-related differences in the beta oscillatory changes are detectable in the employed proprioceptive assessment and that there is a relationship between somatosensory ERD/ERS and the variation of response time. Our findings contribute to the understanding of cortical involvement in the increased response time in the elderly.

Poster #83

Directionally correct antisaccades reduce the effectiveness and efficiency of stimulus-driven saccade networks

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ABSTRACT

The antisaccade task entails suppressing a stimulus-driven response (i.e., response suppression) and looking mirror-symmetrical to the location of an exogenously presented target (i.e., vector inversion): a two-component process that increases reaction times (RTs) and directional errors. Moreover, recent work by our group has shown that an antisaccade trial increases the RTs of a to-be-performed prosaccade (i.e., the unidirectional prosaccades switch-cost). We have proposed that such an effect is due to the lingering inhibition of oculomotor planning mechanisms. In the present investigation, we examined whether the nature of a preceding antisaccade trial (i.e., directionally correct or incorrect) mediates the unidirectional prosaccade switch-cost. Indeed, such an examination provides a basis for determining whether the switch-cost is specifically attributed to the top-down demands of implementing an antisaccade. Participants (N = 26) completed pro- and antisaccades in a pseudo-randomized task-switching paradigm (e.g., AABB or AABA). Notably, a gap paradigm was used in conjunction with an auditory tone to increase the frequency of antisaccade directional errors. As expected, antisaccade task-switch and task-repetition trials produced comparable RTs, whereas prosaccade task-switch trials elicited longer RTs than their task-repetition counterparts (i.e., the unidirectional prosaccades switch-cost). Most notably, RTs for prosaccades preceded by a directionally correct antisaccade were longer than those preceded by a directionally incorrect antisaccade. In addition, RTs for task-switch prosaccades preceded by a directionally incorrect antisaccade did not differ from their task-repetition counterparts. Thus, results suggest that the top-down requirements of suppressing a stimulus-driven prosaccade coupled with the inversion of target's spatial location in mirror-symmetrical space is specifically related to a lingering inhibition of oculomotor planning mechanisms.

Poster #88

Goal-directed grasping: Receptor density influences the fidelity of haptic signals for perceptual and motor processing

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ABSTRACT

Weber's illusion states that an object placed on a high receptor density region (i.e., palm of hand) is perceived as being larger than when placed on a lower receptor density region (i.e., forearm). In the present study, we sought to determine whether Weber's illusion is differentially expressed for manual estimations (i.e., perceptual task) and goal-directed grasping (i.e., motor task). Seventeen participants manually estimated or grasped (with their right hand) differently sized objects (width: 20, 30, 40 and 50 mm) placed on the palm or forearm of their left hand. Because vision was occluded, the representation of object size in this investigation was mediated via haptic cues. Results for grip aperture (GA) in the perceptual task and peak grip aperture (PGA) in the motor task elicited a linear scaling to object size, and this result was consistent across palm and forearm conditions. Notably, however, results for the perceptual task showed that GA values for small (20 and 30 mm) and large (40 and 50 mm) objects in the forearm condition respectively over- and underestimated object size relative to their matched palm condition counterparts. In contrast, results for the motor task indicated that PGAs in the forearm condition were always larger than their palm condition counterpart. Furthermore, aperture variability for both perceptual and motor tasks was greater in the arm as compared to palm condition. Taken together, the results suggest that a lower receptor density region (i.e., the forearm) provides a decreased fidelity signal by which to support perceptual and motor-based processing of haptic information. In other words, results provide no evidence for the expression of Weber's illusion in the perceptual or motor domain.

Poster #90

Archetypal and cued antisaccades yield fundamentally different oculomotor behaviours

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ABSTRACT

The archetypal antisaccade task commonly used in oculomotor research entails the presentation of a single visual target and requires top-down and cognitive suppression of a stimulus-driven saccade (i.e., prosaccade). Furthermore, this task requires the mirror-symmetrical visual remapping (i.e., vector inversion) of a target's location in advance of response initiation. In previous task-switching experiments we have shown that the archetypal antisaccade task selectively increases the reaction times of subsequent prosaccades (i.e., unidirectional prosaccade switch-cost): a switch-cost we attribute to residual inhibition of oculomotor networks arising from the top-down demands of the archetypal antisaccade. However, others researchers have employed an antisaccade paradigm that differ importantly from our earlier work. In this paradigm, two concurrently presented visual targets (equidistant left and right of central fixation and visible until response completion) are presented prior to movement cueing with an annulus surrounding the central fixation area. In turn, the annulus cues one of the two targets and participants are instructed to saccade at the cued target (i.e., cued prosaccade) or saccade to the un-cued target (i.e., cued antisaccade). The use of such a stimulus paradigm has demonstrated a general increase in reaction time of any task (i.e., cued pro- or cued antisaccade) completed after an "antisaccade". It is, however, important to note that the cued antisaccade paradigm does not require the same degree of response suppression as the archetypal antisaccade task due to the presentation of the visual target prior to movement cueing. Moreover, a cued antisaccade is always made directly at a veridical target and is thus void of vector inversion. As such the goal in this investigation was to directly compare the switch-costs associated with both these antisaccade paradigms to asses where the disparity in the switch-cost manifests. To accomplish this, participants alternated making pro- and antisaccades after every second trial using the archetypal antisaccade paradigm in one block of trials and cued antisaccade paradigm in a separate block of trials. Results demonstrated that only prosaccades completed after archetypal antisaccades had increased reaction times (i.e., the unidirectional prosaccade switch-cost). In other words, cued antisaccades did not require sufficient top-down control to inhibit the planning of subsequent prosaccades. In fact, the results yielded no switch-costs with the cued antisaccade paradigm. Furthermore, cued antisaccades had slower peak velocities, shorter movement times, and less variable and more accurate endpoints compared to their archetypal counterparts. Thus, the results demonstrated that the archetypal and cued antisaccade paradigms yield fundamentally different response behaviours and thus do not provide an equivalent methodological basis for evaluating switch-costs in oculomotor control.

Poster #104

Paired pulse electrophysiological investigation of corticocortical interactions of the rostral and caudal forelimb motor areas in the rat

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ABSTRACT

Corticocortical interactions between motor areas are not well understood. In the sensorimotor cortex of rats, intracortical microstimulation shows two distinct cortical areas that produce forelimb movement: a caudal forelimb area (CFA, the equivalent of the primary motor cortex (M1) in rats), and a rostral forelimb area (RFA, a putative premotor area). In this project, we studied how RFA affects the corticospinal outputs of the CFA. We used a paired pulse paradigm in which one stimulating electrode is implanted in RFA, and the other in CFA. A sub-threshold conditioning stimulus was delivered in the RFA prior to a moderately supra-threshold test stimulus delivered in CFA. In different trials, the timing between the pair of stimuli (interstimuli interval or ISI) was varied from 0, 2.5, 5, 10 to 15 msec. Motor evoked potentials (MEPs) were recorded from *palmaris longus, extensor digitorum, biceps brachii,* and *triceps brachii* using implanted microwires and standard electromyography techniques. Data from a total of 19 pairs of RFA/CFA sites were collected in 4 rats. At shorter ISI the stimuli always elicited larger MEP responses than the test stimuli alone, showing a short-latency facilitory influence of the RFA on CFA outputs. At longer ISI, some sites produced facilitation and others suppression of the CFA outputs. The effects of RFA on CFA are similar to the ones described between the ventral premotor cortex and M1 in the macaque monkey (Prabhu, et al. 2009), supporting the hypothesis that RFA acts as a premotor area in the rat.

Poster #107

Corticospinal control strategies underlying voluntary and involuntary wrist movements

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ABSTRACT

The difference between voluntary and involuntary motor actions has been recognized since ancient times, but the nature of this difference remains unclear. We compared corticospinal influences at wrist positions established before and after voluntary motion with those established before and after involuntary motion elicited by sudden removal of a load (the unloading reflex). To minimize the effect of motoneuronal excitability on the evaluation of corticospinal influences, motor potentials from transcranial magnetic stimulation of the wrist motor cortex area were evoked during an EMG silent period produced by brief muscle shortening. The motoneuronal excitability was thus equalized at different wrist positions. Results showed that the unloading reflex was generated in the presence of a corticospinal drive, rather than autonomously by the spinal cord. Although the tonic EMG levels were substantially different, the corticospinal influences remained the same at the pre- and post-unloading wrist positions. These influences however changed when subjects voluntarily moved the wrist to another position. Previous studies showed that the corticospinal system sets the referent position (R) at which neuromuscular posture-stabilizing mechanisms begin to act. In self-initiated actions, the corticospinal system shifts the R to relay these mechanisms to a new posture, thus converting them from mechanisms resisting to those assisting motion. This solves the classical posture-movement problem. In contrast, by maintaining the R value constant, the corticospinal system relies on these posture-stabilizing mechanisms to allow involuntary responses to occur after unloading. Thus, central control strategies underlying the two types of motor actions are fundamentally different.

Poster #108

It is possible to use static posturography in the assessment of sensorimotor gating

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ABSTRACT

The aim of this study was to show the possibility of using static posturography in the assessment of sensorimotor gating, which is the ability of the nervous system to filter unimportant information that disturb in the information processing. Fourteen subjects took part in the experiment. The inhibitory mechanisms of startle reflex were used as the measure of sensorimotor gating. It was evoked by a strong acoustic stimulus which was preceded with the weaker signal of a similar character (prepulse inhibition). A stabilographic platform was used to measure sensorimotor gating. Subjects executed trials in quiet standing with eyes opened and eyes closed. They were provided with the acoustic stimuli of 106 dB pitch which lasted 40 ms each while they were exposed to 70 dB broadband (white) noise. Prepulse stimuli were provided to the subjects to provoke startle response inhibition. We hypothesized that these stimuli would elicit postural reactions. Our results show that with static posturography one is able to observe the startle response to the acoustic stimuli. The postural sway caused by the reaction to a strong acoustic stimulus is significantly smaller when this stimulus is preceded by the signal of lower pitch (prepulse). This indicates the presence of sensorimotor gating. Such assessment is only possible in eyes open conditions. The results of this study indicate the possibility of the use of simple yet effective method of static posturography in the diagnosis of sensorimotor gating in humans.

Poster #111

The effect of short- and long-term whole body vibration on postural stability

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ABSTRACT

The study aimed to establish the short- and long-term effects of mechanical vibration on postural stability in young men. The sample consisted of 28 male subjects randomly allocated to four comparative groups, three of which exercised on a vibration platform whose parameters were set individually for the groups: I – 2 mm/20 Hz, II – 2 mm/40 Hz, III – 2 mm/60. Group IV was the control group. The stabilographic signal was recorded in the ML and AP planes for subjects standing in a free standing position before the test commenced, after a single application of vibration, immediately after the last set of exercises of the 4-week vibration training, as well as one week after the training ended. Stabilographic signal was developed by a method of stabilogram decomposition into two components: rambling and trembling. The subjects were exposed to vibration 3 times a week for 4 weeks, each training session containing a set of 5 static exercises going on for 1 minute each. Long-term vibration training significantly shortened the rambling and trembling paths in the frontal plane ($p<0.05$). The path lengths were significantly reduced in the frontal plane also one week after training end-date ($p<0.05$). Group III (60 Hz, 2 mm) was the only one where the COP sway significantly decreased in both AP and ML planes one week after vibration training ($p<0.05$) compared with the pre-test recordings. To induce favourable adaptive changes in postural stability, long-term vibration training involving a frequency of 60 Hz and amplitude of 2 mm is recommended.

Poster #113

Correlation of impaired hand and foot force control and cervical spinal cord structure in early stages of cervical spondylotic myelopathy

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ABSTRACT

Objective clinical measurements sensitive to the early occurring changes in cervical spondylotic myelopathy (CSM) are lacking. We investigated early occurring force control deficits in CSM and related these changes to cervical spinal cord structure. Twenty early stage CSM patients and a group of control subjects of similar age were included. A visuomotor tracking task was used to measure force control at low absolute force levels (3, 6 and 9N) in the precision grip and hallux. Diffusion tensor imaging (DTI) and conventional T2-weighted MRI was performed to assess structural integrity of the cervical spinal cord. DTI parameters were extracted from regions of interest covering the entire cross-section of cervical spinal cord (C1-C5). All patients presented cervical pain but few had other neurological symptoms. Groups were similar in clinical assessments of maximal grip strength and dexterity (Pick-up test) and most patients (60%) had normal functioning according to the European Myelopathy Score. Only 4 patients (20%) showed signs of spinal cord damage on T2-weighted MRI. Force tracking showed 35% greater error in both hand and foot tasks in patients compared to controls ($P=0.008$). All subjects performed the hand task with less error compared to the foot task ($P < 0.001$). Mean release duration was longer in patients than in controls (133ms±30 vs 96ms±34, $P > 0.001$). Both groups took in average about 30ms longer to release force in the foot compared to the hand. DTI revealed lower mean spinal cord fractional anisotropy (FA) in patients compared to controls (0.50±0.03 vs 0.52±0.03, $P=0.008$) and radial diffusivity was higher ($P=0.04$). In patients, mean error during force tracking (hand and foot combined) correlated negatively with FA ($R=-0.47$, $P=0.04$). Variation in spinal cord FA fully explained the group difference in tracking error when added as covariate. Force control deficits were found in CSM patients in the early stage. Impaired accuracy of force modulation (increased error) but not release duration was related to and fully explained by reduced cervical spinal cord structure. These findings suggest that force tracking may be clinically useful in detecting and quantifying subtle sensorimotor deficits early in CSM.

Poster #124

Modulation of EMG activity and spinal reflex during a balancing task using lower limb under psychological pressure

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ABSTRACT

In competitive sports, athletes must demonstrate their optimal performance under changing psychological conditions, of which psychological pressure is a major factor. Athletes must try to overcome the negative effects of psychological pressure. To date, the relationship between psychological pressure and motor neuron activity in the spinal cord, and peripheral muscular activity in the lower limbs have remained unknown. Therefore, the effect of psychological pressure on muscular activity of lower limb and spinal reflex excitability during a postural control task was investigated. Healthy male participants (n = 13) performed a balancing task by standing on a balance disk with one foot. In each trial, participants were requested to stabilize their posture on the disk for 20 s. After six acquisition trials, they performed a single, counterbalanced, non-pressure trial, and a single pressure trial, in which a performance-contingent cash reward, or punishment was given. The Hoffmann reflex was obtained from the right soleus (SOL) muscle by stimulating the tibial nerve. Eighteen stimulations at 1 Hz were administrated in each trail. EMGs of the SOL and tibialis anterior (TA) muscles were recorded. Stress responses were successfully induced under pressure, as indicated by increased state anxiety, mental effort, and heart rate. Results indicated that the increment of EMG amplitude of TA muscles under pressure was significantly associated with the increased co-contraction rate between SOL and TA muscles. Moreover, the amplitude of the SOL H-reflex in pressure trial was significantly smaller than in non-pressure trial. In spite of these neurobehavioral changes, 12 of 13 participants succeed in the postural control task under pressure. These results suggested that increased co-contraction and H-reflex inhibition contributed to optimal postural control in stressful situations. It is suggested that disynaptic reciprocal inhibition and presynaptic inhibition associated with the motor control system shifted to the domination of the higher central nervous system, which modified the mechanisms of spinal reflex excitability under psychological pressure.

Poster #133

Learning and retention of an asymmetric bimanual task

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ABSTRACT

While asymmetric bimanual actions abound in normal life, we frequently experience that dissociating the two hands is difficult. From studies of acallosal patients it is evident that the corpus callosum plays a vital role in learning bimanual tasks. It remains unclear, however, the extent to which healthy humans can achieve independent hand control as required in some motor skills. To examine to what extent interhemispheric communication can be modified through practice, a discrete/rhythmic bimanual task in healthy subjects was tested and the performances in individual arms were analyzed. We hypothesized that bimanual performance would asymptote to the level of the unimanual performances by long-term practice. To evaluate the long-term effect of such practice performance was tested again after 3 months. While seated, subjects were asked to rotate their forearms in the horizontal plane with the elbow positions fixed. They were instructed to move their left arm as fast as possible to a target without disturbing the continuous right-arm that performed smooth oscillations with a fixed frequency, 0.75 Hz. The task goal was to simultaneously show fast peak velocity and small perturbations of the continuous rhythmic movement, similar to unimanual performance. Thus, the dependent variables were peak velocity of the left arm and RMS phase error of the right arm oscillation at the left-arm reaching onset. 18 healthy right-handed subjects practiced for 20 daily sessions. Additionally, they participated in 3 retention sessions 3 months after the end of practice with the same experimental parameters. Each session had 45s-long 15 bimanual and 1 unimanual trials. After each trial, subjects received knowledge of results for both arms with short break. During each trial, subjects performed about 10 reaches with unpredictable cue onset. Results showed increased mean peak velocity in the left arm across practice, but without statistical difference between bimanual and unimanual conditions. For the right arm, the RMS phase error decreased over practice in the unimanual condition, but subjects were unable to reduce the interference in the bimanual condition. For the 3-month retention sessions, subjects showed the same level of performance variables for both hands as they performed at the last practice session. Although the left arm's movement was only minimally impacted by the addition of the right arm task, the right arm's perturbation was not attenuated over extensive practice to reach the unimanual performance quality. However, it is noteworthy that the invariant performance in the right-arm may also indicate learning because we expected that higher peak velocity may be associated with stronger perturbation to the right arm oscillation. In conclusion, these results suggest an asymmetry in the adaptability of the two arms' tasks, and the asymmetric results were reproduced after 3 months.

Poster #135

Trajectory deviations in individual and social aiming tasks

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ABSTRACT

The original purpose of the present study was to test the response co-representation hypothesis of the joint Simon effect (JSE) by analyzing the trajectories of aiming movements executed in a JSE task. In JSE tasks, pairs of participants sit beside each other and perform one half of a spatial compatibility task. Coloured stimuli are randomly presented at one of two potential locations and each participant is asked to respond to only one colour (relevant dimension) while ignoring the spatial location (irrelevant dimension). The JSE refers to the finding that, even though participants only respond to one of the stimuli (effectively performing a go-nogo task in a social context), spatial compatibility effects emerge – response times (RTs) to targets presented in front of the participant are shorter than when the target is presented in front of the partner. The dependency of the JSE on the social context is demonstrated via comparisons with RTs on an individual go-nogo task where the participant responds to exactly the same stimuli, except that they perform the task alone (i.e., no partner responding to the other stimulus). RTs are not affected by the spatial location of the stimulus in the individual go-nogo task. The dominant explanation of JSE is that it emerges because the actor represents their partner's response as well as their own and that this co-represented response activates the same set of mechanisms that cause facilitation and interference when an actor performs the entire two-choice task alone. On the individual go-nogo task, there is no partner, no response co-representation and, hence, no response conflict or facilitation. In the present study, we aimed to test this hypothesis by asking participants to execute goal-directed aiming movements in several Simon tasks. Previous studies building on action-centred attention research has shown that movements deviate towards the location of the target stimulus on incompatible trials when individuals perform the entire two-choice task alone. It is thought that the deviations on incompatible trials occur because competing responses are activated to the relevant colour and irrelevant spatial dimensions and the presence of the non-target response codes bias the initial response trajectory towards the location of the stimulus. Thus, we predicted that if response co-representation is the main process underlying the JSE, then trajectory deviations should be observed in the two-choice and joint Simon tasks, but not in the individual go-nogo task. The results of the study were that, although an influence of social context was noted, deviations were observed in all three tasks. Although we were not able to address the main research question, the data suggest responses are activated to each onset stimulus, regardless of the action context, and thus support the hypothesized tight link between attentional capture and response activation that is central to related models of action-centred attention.

Poster #141

Deficient cortical activity during motor inhibition in schizophrenia

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ABSTRACT

Deficient inhibition is one key mechanism in schizophrenia as evidenced by numerous behavioural and imaging studies. Functional MRI (fMRI) has shown altered activation patterns during inhibition tasks in patients with schizophrenia (e.g., Kaladjian et al, 2007; Criaud and Boulinguez, 2013). However, findings across studies are not consistent. The aim of this study was to investigate cortical activation during motor inhibition in patients with schizophrenia. 22 stabilized patients with schizophrenia (mean age: 32, 18 males) treated with atypical antipsychotic medication were compared with 18 healthy subjects (mean age: 30, 10 males). Subjects underwent a single 3T-MRI session including event-related fMRI (EPI BOLD sequence, 4 runs). Participants performed a volitional inhibition task consisting in a fingertip Go-NoGo task, with 30% randomized NoGo events. Preprocessing and analysis was performed using spm5 (*www.fil.ion.ucl.ac.uk/spm/*). Two analyses were performed: (i) whole brain statistical maps of NoGo>baseline (activation) and baseline>NoGo (deactivation) with age as covariate ; (ii) extraction of NoGo contrast values using Marsbar toolbox in 12 cortical regions of interest (ROIs) involved in NoGo inhibition (Criaud and Boulinguez, 2013). Results were compared between controls and patients. Patients and controls suppressed finger movements similarly during NoGo trials ($p=0.24$). Whole brain analysis of NoGo>baseline showed activation in the bilateral inferior parietal lobule (BA39-40), the cingulate gyrus (BA32), the left middle frontal gyrus (BA46) and the right superior temporal gyrus (BA22), in both groups, without any differences between groups. For baseline>NoGo, both groups showed a widespread deactivation in the left precentral gyrus (BA4) and the supplementary motor area (BA6), bilaterally. Interestingly, controls deactivated the following areas more than patients (FDR $P<0.05$): bilateral middle cingulate (posterior BA32), left precentral (BA4), left inferior frontal (BA48), right middle temporal (BA37) gyri and right inferior parietal lobule (BA40). The ROI analysis revealed a stronger deactivation in the left medial frontal (BA9) and the right superior frontal (BA6) gyri in controls compared to patients. These areas matched clusters found in the whole brain analysis. Patients with schizophrenia showed widespread reduced deactivation during correct NoGo trials in areas known to be involved in motor inhibition (Criaud and Boulinguez, 2013). Deactivation during NoGo likely reflects neural inhibition involved in suppression of the prepared Go response (Smith et al, 2012). The deficient brain processing during successful motor inhibition suggests that patients with schizophrenia may use alternative inhibition strategies to achieve similar performance levels to controls.

Poster #144

Movement and brain dynamics at various scales

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ABSTRACT

Movements can be classified via their underlying phase flow topology [Jirsa and Kelso 2005, Huys et al. 2008]. Dynamical systems theory states that dynamical systems belong to the same class if, and only if, they are topologically equivalent. Following this notion, it was shown that humans can employ two different motor control mechanisms and naturally switch from a mechanism involving a fixed point plus separatrix to one involving a limit cycle (corresponding to discrete and rhythmic movements, respectively; [Huys et al. 2008]). In addition, evidence was found suggesting the existence of a system involving phase flow changes at the time scale of the movement (unlike in the other two cases). We searched for neural correlates of these motor classes in electroencephalograms (EEG). Ten participants performed wrist movements at 7 frequencies between 0.67 and 3.2 Hz under instructions to move as fast or as smooth as possible in a continuation paradigm. Wrist movements and 64-electrode EEG were recorded simultaneously at 1024 Hz. Reconstructed vector fields from the wrist movements [Huys et al. 2008, Strogatz 1994, van Mourik et al. 2006] indicated that at high frequency the movement were always limit-cycle governed. At low frequencies, the movement were either fixed-point based (fast instruction) or involved flow changes. For the EEG analysis, we (i) focused on pre-and post-movement *b*-band (de)synchronization, and (ii) searched for low-dimensional dynamic patterns on the time scale of movement. The results showed that (i) *b*-band (de)synchronization was strongly present during fixed point movements but less so during limit cycle movement. In the 'changing phase flow' regime, *b*-band activity was least structured. As for (ii), via PCA we found evidence that the EEG dynamics contained a structured 3D pattern involving a slow and fast evolution as the movements were governed by a (local) fixed-point dynamics, which came to approximate a 2D circular structure for limit-cycle movements. In the absence of fixed point or limit cycle dynamics at the movement level the first 3 PCA modes appeared unstructured (in the 'change flow' case at the behavioural level). These observations suggest that (i) the degree of *b*-band (de)synchronization co-varies with parametric changes in movement kinematics but does not uniquely map onto its (dynamic) classification, and (ii) suggest that the flow topology characterizing behavioural function may have its reflection in the brain's dynamics, and hints at the existence of a dynamic isomorphism in a similar spirit as advanced by Gestalt psychology [Kölher 1938].

Poster #154

Brain networks underlying motor learning by observing assessed using resting-state fMRI

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ABSTRACT

Recent research has demonstrated that motor learning can be achieved not only through direct, firsthand experience, but also by merely observing another individual learning to move. These findings demonstrate that neural representations of novel environments can be acquired through observation. When we observe the actions of others, we activate those same brain regions involved in performing those actions ourselves. However, the brain's ability to learn how to make movements through observation is still not well understood. Here, we use resting-state fMRI coupled with a force field learning paradigm to investigate the neural basis of motor learning by observing. On day 1, subjects grasped the handle of an InMotion2 robotic arm and performed straight reaching movements in a null field in which the robotic arm did not apply force to the hand. Next, subjects underwent a baseline resting-state fMRI scan. On day 2, subjects watched a video of an actor learning to perform straight reaching movements while the robotic arm applied a counter-clockwise force field. Subjects then underwent a post-learning resting-state fMRI scan. Finally, to assess motor learning behaviourally, subjects performed straight reaching movements in a clockwise force field. Motor learning scores were calculated as the magnitude of proactive interference in terms of movement curvature. A seed-based correlation analysis was carried out to assess changes in resting-state functional connectivity (FC) from day 1 to day 2 that were related to our behavioural measure of observational motor learning. We revealed a network involving V5/MT, cerebellum, primary motor cortex, primary somatosensory cortex and supplementary motor area whose activation was significantly modulated by the amount of observational motor learning that was achieved (as assessed on day 2, after scanning). This network may be engaged to facilitate motor learning by observing.

Poster #156

Acquisition and retention of force field adaptation during human gait

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ABSTRACT

When subjects start walking in an altered force environment, they initially show large movement deviations from baseline. After many repetitions, they gradually modify their motor commands to take into account the new force environment and movement kinematics returns towards baseline. It has been shown using different paradigms that subjects retested with the same perturbation 24 hours after initial exposure perform better, illustrating retention of the previous experience. The aim of the present study is to evaluate both acquisition and retention of motor adaptation to a perturbation resisting dorsiflexion during the swing phase of gait. Eleven healthy subjects were asked to walk on a motorized treadmill while wearing a robotized ankle-foot orthosis (EHO) on the right leg. On the first day, subjects performed the task for three periods: before (Baseline, 10 min), during (Adaptation, 5 min) and after (Post, 5 min) exposure to a force field applied during the swing phase and resisting ankle dorsiflexion. During the Adaptation period, subjects were instructed to resist the perturbation to walk normally. Subjects performed the same task after a 24 hours delay to assess retention. Ankle kinematic data was collected with an optical encoder and the mean absolute deviation from baseline during swing (absolute error) was calculated. A two-way repeated measure ANOVA (Period [Early / Late adaptation] X Day [1 / 2]) was performed to evaluate the evolution of kinematic errors during adaptation periods. With 11 subjects tested so far, a significant main effect of the Period on the absolute error is observed (p=0.027), with a trend for a Period X Day interaction (p=0.122). Post-hoc analyses show that absolute error tend to be reduced on Day 2 compare to Day 1 in the Early adaptation period (p=0.074) but not in the Late adaptation period (p=0.238). When exposed to the same perturbation on two consecutive days, subjects perform better in reducing absolute error early in the adaptation period, illustrating retention of the motor learning. These results are in line with other motor adaptation studies showing that peak performance can be reached within minutes of practice in this kind of task, and that performance can be maintained after a delay without practice.

Poster #157

Acquisition and retention of force field adaptation during human reaching

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ABSTRACT

Adaptation to an altered force environment (force field) during reaching movements provides an interesting model to study motor learning. Learning involves several steps: improvement in performance (acquisition), transfer to longer-term memory (consolidation), and the ability to recall the stored motor memory (retention). The aim of this study was to assess the acquisition and the next day retention of motor adaptation to a force field perturbing a reaching task. Thirteen right-handed healthy subjects (8 females, age 26.6±5.0) performed a reaching task in a 2D virtual environment over two consecutive days. The task consisted in moving the right index from a central position to one of two targets (one toward (Near target), one away (Far target) from the body) as fast and precisely as possible (ballistic movements). On the first day, subjects performed the task for two periods: before (Baseline, 100 trials / target) and during (Acquisition, 50 trials / target) exposure to a force field applied at the elbow joint by a KINARM Exoskeleton robot. On the second day, subjects started the task directly with force field exposure (Retention – exactly similar to Day 1 Acquisition period), followed by a period without perturbation to assess the presence of after-effects. Motor performance was quantified by measuring the initial directional error (in absolute value), i.e. the angle between the shortest (ideal) trajectory connecting the starting position to the target and the actual initial trajectory (prior to the peak acceleration). Paired sample t-tests were used to determine whether: 1- performance at the end (trials 48 to 50) of the Adaptation period on Day 1 was better than at the beginning (trials 1 to 3) (motor acquisition); 2- performance at the beginning of the Adaptation period on Day 2 was better than at the beginning of adaptation on Day 1 (motor retention). Reaching movements were quite linear at baseline, with average initial directional errors of around 7° at the end of baseline (Far target = 6.0±3.2°; Near Target = 7.5±4.2°). Force field induced substantial errors compared to baseline, and subjects gradually adapted to the perturbation. On Day 1, the initial directional errors went from 21,0°± 7.3 at the beginning of the Adaptation to 11.0°±6.4 at the end for the Far target ($P < 0.01$) and from 28.3°± 5.1 to 10.9°±4.9 for the Near target ($P < 0.01$). Initial directional errors at the beginning of the Adaptation period on Day 2 were significantly smaller than on Day 1 for both the Far (15.6°±5.3; $P = 0.04$) and the Near (15.2°±4.3; $P < 0.01$) targets. The reduced initial directional errors on the first reaching movements on Day 2 support the idea that motor strategies for force field adaptation are stored in motor memory and recalled on Day 2. In the future, this type of experimental approach could be used to test the effect of extrinsic factors (e.g. pain) on the consolidation of motor memories.

Poster #162

Influence of cycling cadence and crank resistance on range of knee angles in which flexor and extensor muscles co-activate during cycling

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ABSTRACT

Muscle activities (surface EMG) from quadriceps and hamstrings muscle groups were recorded while able bodied subjects were cycling on a recumbent bike and the range of knee angles were assessed in which both muscle groups were active. A muscle was considered active when its EMG amplitude exceeded the 35% of its maxima recorded during the movement. We studied the range of knee angles at which the flexor and extensor muscle groups co-activate and the dependence of this range on cycling cadence and crank resistance. Forty-one subjects performed cycling movements in 6 conditions: fast and slow cycling against 3 crank resistances: low, moderate, high. A ZEBRIS CMS70P motion-analyzer system has been used to record surface EMG signals with sampling frequency of 1000Hz. Marker coordinates were recorded (25Hz) to compute knee angles. Data were collected and processed from at least 10 cycles per conditions. The two muscle groups co-activated in a certain range of knee angles in each condition. This co-activation range (CR) was determined for each condition separately and they were compared by Student's T-test ($p<.05$). Co-activation occurred before the knee started to extend. The size of CR was significantly larger during fast than slow cycling in the case of moderate and high resistance but cadence did not have significant effect on CR size in low resistance condition. Resistance had an effect on CR when cycling fast: higher resistance was related to larger CR. During slow cycling the resistance did not have significant effect on CR size. Higher cadence is generally associated with wider range of knee angles in which knee flexors and extensors co-activate and extensor offset occurs at a more flexed knee position when cycling faster. This shifted offset also happens against increased resistance when cycling fast. The range of co-activation varies with the power output and efficient cycling may be regulated by shifting extensor activity offsets when power output alters either due to change of cadence or crank resistance. Supported by TAMOP-4.2.1,B-11/2/KMR-2011-0002.

Poster #164

The effect of a thumb motor training task on median nerve sensory processing

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ABSTRACT

After long periods of practice, almost any motor skill can be executed quickly, accurately and with little or no conscious deliberation; at this point the behaviour is referred to as automatic (Ashby et al. 2012). Early work investigating measured somatosensory evoked potentials (SEPs) changes following a simple task (repetitively typing the numbers 7,8,9) in sequence using the 2nd to the 4th digits (Murphy et al. 2003). It is known that repetition of motor behaviour leads to a decrease in functional activation across all motor areas (Dassonvile et al. 1998) hence it is important to investigate the neurophysiological and behavioural consequences of more complex. This study sought to measure changes in early SEP peak amplitudes following a more complex thumb motor training task. Twelve participants performed 20 minutes of a complex typing task utilizing the numbers, 7, 8, and 9 but in randomly generated sequences of 6 (e.g. 7, 9, 8, 6, 7, 7), using a muscle directly innervated by the median nerve, the abductor pollicis brevis (APB). Spinal, brainstem and cortical SEPs to median nerve stimulation at the wrist were recorded before and after a motor training typing task using the APB. SEPs were collected at inter-stimulus intervals of 405 milliseconds and 201 milliseconds, and 1500 sweeps were averaged. Reaction time and accuracy of key presses were also recorded. Paired t-tests were used to compare changes in both SEP peaks and performance measures. Reaction time to key press increased significantly (p= 0.0004) following the 20 minute motor training task while accuracy remained similar (.969 and .979). Significant increases were also observed for the P22-N24 (p=0.0001) and P22-N30 SEP (p= 0.0392) complexes. The P22-N24 complex increased by 59.6%, while the P22-N30 complex increased by 13.5% following the motor task intervention. The motor training resulted in learning as indicated by the improved reaction time. Accuracy was unchanged most likely due to a ceiling effect because it was already nearly perfect prior to motor training. The N24 SEP peak reflects increased activation of neurons within the pathways between the cerebellum and the primary somatosensory cortex (S1; Restuccia et al. 2001), while the N30 SEP peak represents a complex connection between various SMI regions which include the thalamus, premotor areas, basal ganglia and primary motor cortex (Cebolla et al. 2011). This study has demonstrated changes in early SEP peaks related to SMI concomitant with improved performance following a motor training task. This suggests that these SEP peaks may be important neurophysiological markers of motor learning.

Poster #165

The effect of experimental pain on motor training performance and sensorimotor integration

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ABSTRACT

Effective sensorimotor integration (SMI) is essential when integrating and processing afferent input and also when learning new skills. Experimental pain induced by topical capsaicin is known to affect neuroplasticity of the tongue MI, as well as motor performance (Boudreau et al. 2007). This suggests that nociceptive input modulates neuroplasticity associated with motor training, but less is known about neural plasticity of somatosensory processing. The aim of this study was to use early somatosensory evoked potentials (SEPs) to investigate the interactive effects of nociceptive input on motor training on sensorimotor processing. Two groups of twelve subjects were randomly assigned to either intervention (capsaicin) or placebo (lotion) conditions which was applied in the to a 50 cm^2 area on the lateral aspect of the right elbow. Spinal, brainstem and cortical SEPs elicited via median nerve stimulation at the wrist were recorded before and after a motor training typing task involving the three middle digits of the right hand. SEPs were collected at inter-stimulus intervals of 405 and 201 ms, averaged at 1500 sweeps and were performed pre intervention, post application of capsaicin or placebo cream and post motor training. Participants performed a randomly generated motor sequence acquisition involving pressing the numbers 7, 8, 9 on a numeric keypad for 20 minutes. Reaction time and accuracy were recorded. Repeated measures ANOVAs were used to compare changes in both SEP peaks and performance measures. Following motor learning, reaction time was significantly decreased for both conditions F= (23, 1) 59.575 (α = 0.000) (15.94% for the placebo group and 23.57%. for the capsaicin group). Accuracy increased in the intervention condition with a significant Accuracy*Condition interaction between the two groups F = (23, 1) 5.236 (α = 0.032) with the capsaicin group improving. There were significant increases in the P22-N24 and the P22-N30 SEP complexes following the motor training task for both conditions ([F (23, 2) = 4.462, p<.0.005] for the N30 peak, and ANOVA [F (23,2) = 3.533, p<.0.005] for the N24 SEP peak with no interactive effect. Post hoc paired t-tests indicated that the significant increase occurred following motor training for the N24 (p = 0.009) and N30 (p=0.04). These findings provide support for the enhancement of knowledge transfer with the presence of non-target stimuli (pain). Under certain circumstances, the presence of additional stimuli can increase the ability to detect, or interpret a pattern of target stimuli [2, 3]. The motor learning task produced differential behavioural and neural changes on SEP amplitudes, which were not significantly different in the presence of capsaicin.

Poster #169

The effects of motor learning on the cerebellum and motor cortex

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ABSTRACT

Although there are a plethora of studies showing the response of the motor cortex to motor skill development, there are few studies demonstrating the effect on the cerebellum. Stimulation of the cerebellum 5-7 ms before stimulation of the motor cortex can lead to inhibition of motor evoked potentials (MEPs), a process referred to as cerebellar inhibition (CBI). This study aimed to develop better protocols for cerebellar inhibition (CBI) curves and to observe the effect of complex finger-tapping tasks which have been shown to activate the cerebellum on the CBI curves found within a healthy population. For series one, EMG activity was recorded from the right first dorsal interosseous (FDI) muscle in 11 healthy subjects before and after a finger-tapping task consisting of a randomly generated motor training task involving pressing the numbers 7, 8, 9 on a numeric keypad for 20 minutes. CBI was performed and measured after applying a conditioning stimulus of 70, 80 or 90% of maximal stimulator output to the right cerebellar hemisphere prior to cortical stimulation. For series two, CBI was assessed in 12 subjects before and after a 15-minute task where subjects typed eight-letter sequences of the letters Z, D, F, and P. CBI changes following motor training were compared using a repeated-measures ANOVA comparing the three conditioning stimulus intensities of 70,80 and 90% for series one; for series two, the ANOVA compared the Ipsilateral Cerebellar Inhibition Threshold (ICIT), defined as the level of stimulator intensity that elicits MEPS at or near to fifty-percent inhibition, ICIT+5%, and ICIT+10%. Mean reaction time and accuracy were analyzed in both. In series one, there were no changes with the motor learning task. In series two, a significant decrease in CBI was seen following the finger-tapping task at ($P<0.0001$), with no interactive effect of level. Mean reaction time showed a significant increase in speed following the practice time for both series ($p<0.001$ series 1 and $p= 0.0012$ series 2). No changes were apparent in accuracy. The ICIT approach has shown clear changes following a finger-tapping task, which was missed by a less sensitive approach. The ICIT model functions on the premise that individuals respond differently at varying levels of stimulator output. This model assesses these individual responses and normalizes the data to determine the net group effect. This model is a more sensitive measure of CBI which can be used to assess performance-induced plasticity in the cerebrocerebellar pathway.

Poster #171

Asymmetry in inhibition and facilitation between dominant and non-dominant hemispheres in right-handed individuals

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ABSTRACT

Past transcranial magnetic stimulation (TMS) studies have demonstrated asymmetries of the left and right hemispheres in motor evoked potential (MEP) thresholds in intrinsic and, less commonly, extrinsic hand muscles, however the results of these studies have been contradictory (Cicinelli et al. 1997, Civardi et al. 2000, Triggs et al. 1997). Recent work has demonstrated asymmetry in TMS recruitment curves between the dominant and non-dominant hands of both left and right handed individuals, with the non-dominant cortex demonstrating a greater slope in both groups (Daligadu et al. 2012). This current study sought to explore the possible mechanisms of this difference by comparing short and long interval intracortical inhibition (SICI and LICI) as well as short interval intracortical facilitation (SICF) between the dominant (D) and non-dominant (Nd) hemispheres. This functional usage may develop altered pathways of activation not only in the activation of neurons but also in local excitability of the primary motor cortex (M1), manifesting in the different motor control of the opposing hands[4]. We hypothesized that due to a life-time of use dependent plasticity that the dominant hemisphere would have greater SICI and less SICF. 14 healthy, right-handed male participants (Mean age = 19.7) were recruited with approval of the university REB. Handedness was determined using the Edinburgh Handedness Inventory (Oldfield, 1971). Surface electromyography (EMG) data was collected using surface electrodes on the first dorsal interosseus (FDI) muscle. TMS was applied to the optimal region of the right and left motor cortices to elicit a MEP of approximately 1 mvolt in the FDI muscle of the D and Nd hand. The average of 16 sweeps for SICI, LICI, and SICF were compared between the dominant and non-dominant hands using paired t-tests. Results indicate that in right hand D participants, there was significantly increased SICI in the D hemisphere (P=0.048). The right hand D participants also showed trends of increased SICF in the Nd hemisphere, as well as increased LICI in the D hemisphere, but this did not reach significance. The findings support the hypothesis of greater inhibition in the D hemisphere, suggesting a conditioning effect with handedness. Future work needs to identify if similar differences exist in the D and Nd hemispheres of left handed participants. As well, these findings suggest that that the non-dominant hand may have a greater potential for neural plasticity which could be very relevant in rehabilitation settings.

Poster #177

Postural reactions to tilts of the base of support: contribution of foot afferents

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ABSTRACT

Individuals at high risk of fall are greatly restricted in their mobility, and neural mechanisms underlying their impaired reactions to perturbation are poorly understood. Several studies suggest that corrective reactions to perturbations may be mediated by plantar muscle afferents projecting to leg and thigh muscles (Schieppati 1995, Marque 2001, 2005), but the exact contribution of those projections is not known. The goal of this study was to assess the contribution of foot muscle afferents in corrective postural reactions by applying electrical stimulation to the posterior tibial nerve (PTN) at different phases of unexpected forward and backward tilts. Eight healthy subjects participated in this study. EMG activity of right soleus (SOL) and tibialis anterior (TA) muscles were recorded before and during perturbation. First, forward and backward tilts were randomly induced on a force platform where subjects were standing, in order to determine basic patterns of reactions to perturbation. Second, a single-pulse electric stimulus of the right PTN (2-2.5 x motor threshold; level of the internal malleolus) was applied during standing or 150 ms after the onset of tilts. Responses induced in SOL and TA by this stimulation were assessed to determine differences in terms of latency, sign (facilitation or inhibition) and amplitude between the three conditions (ANOVA). During quiet standing, SOL but not TA was activated. PTN stimulation induced responses in SOL composed of an inhibitory short-latency response (SLR; 53±6 ms), a facilitatory medium-latency response (MLR; 67±6 ms) and a facilitatory long-latency response (LLR; 92+/-5 ms). During backward tilt, SOL muscle activity decreased while TA activity increased to appropriately recover balance. Latency of responses to PTN stimulation did not change but SLR became facilitatory (185% vs. 64% standing; $p < 0.001$) and the LLR became inhibitory (57% vs 141% standing; $p < 0.01$). During forward tilt, SOL increased its activity, whereas TA became silent. The SLR induced in SOL became inhibitory (49%) and LLR was variable, but mainly facilitatory. Such reflex reversal was not observed in TA as fewer subjects displayed response in that muscle during all three conditions. Preliminary data show that responses to PTN stimulation are modulated during backward/forward perturbation. Furthermore, whereas SLR in SOL does not vary in the same direction as the EMG activity underlying postural reactions, LLR reflects the postural response of this muscle. Results suggest a contribution of the foot afferents to postural reactions and concur with previous findings, suggesting higher relevance of the LLR in functional tasks.

Poster #179

Patterns of residual corticospinal influences in post-stroke spasticity

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ABSTRACT

Spasticity, weakness and abnormal co-activation in post-stroke patients result from limitations in the range of regulation of stretch reflex thresholds. We investigated whether the deficits in residual corticospinal influences contribute to the limitation in the regulation of reflex thresholds and as a result to spasticity in post-stroke subjects. Spasticity zones in the elbow range of motion were identified as the angular ranges in which flexor or extensor muscles became active during passive muscle stretches, despite the instruction to fully relax elbow muscles. A single-pulse transcranial magnetic stimulation (TMS) was applied to the site of the motor cortex projecting to motoneurons of elbow flexors and extensors. Responses to TMS (motor evoked potential or MEPs) were recorded at a flexion and an extension position of the elbow joint. To exclude the influence of background motoneuronal excitability on the evaluation of corticospinal influences, MEPs were elicited during the EMG silent period produced by brief muscle shortening prior to TMS. MEPs were recorded at the two elbow positions established passively, by the experimenter, or actively, by the subject. In control subjects, MEPs at different positions established passively were substantially smaller than those obtained at the same positions established actively. In these subjects, the corticospinal facilitation of flexor motoneurons was usually larger whereas that of extensor motoneurons was smaller at the actively maintained flexion than at extension position (reciprocal pattern of position-related changes in flexor and extensor MEPs). In most post-stroke subjects with high clinical spasticity scores, the corticospinal facilitation of both flexor and extensor motoneurons was greater at the actively established flexion than extension position (co-facilitation pattern). In subjects with lower spasticity scores, the pattern of position-related modulation of corticospinal influences on extensor but not flexor motoneurons resembled that in control subjects. Results show that spasticity is associated with substantial changes in the corticospinal influences on flexor and extensor motoneurons. Corticospinal co-facilitation of the two groups of motoneurons may be related to the necessity to overcome resistance of spastic muscles during active changes in the elbow joint angle.

Poster #180

Dissociating central set and motor preparation using transcranial magnetic stimulation

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ABSTRACT

The execution of movement relies on the integrity of neural circuitry within the brain and also the central and peripheral nervous system pathways that connect the brain to the muscles of the body. In humans, cortical activity has been observed as early as 800 ms prior to voluntary movement initiation and spinal motor activity as early as one second prior to movement initiation. Such pre-movement activity optimizes the output of the motor system to generate contextually-appropriate movement. Two processes associated with pre-motor response are central set and motor preparation. Though these processes are functionally comparable, differences in the central nervous system networks that contribute to these processes suggest that they play different roles in specific pre-movement elements. Identifying these differences is an important precursor to better understanding how humans modulate preparatory activity to enhance behaviour. The purpose of this study was to determine whether disrupting activity in the dorsal pre-motor cortex (PMd) would alter the cortical activity of the processes associated with movement preparation. It was hypothesized that repetitive TMS would disrupt cortical activity in tasks related to movement preparation, but not in those related to central set. 3 participants completed 2 types of cued reaction-time tasks. The GO condition (designed to reveal central set activity) required the participant to respond as quick as possible after each auditory tone (30 trials). The NOGO condition randomly presented 25 go and 5 no-go tones. rTMS was applied to the PMd, a region strongly associated with motor preparation and initiation in the hand and forelimb. Participants repeated the 2 conditions. The contribution of PMd to the processes associated with central set and motor preparation was determined by assessing the change in preparatory EEG activity at the FCZ, CZ, C1 and C3 electrode sites pre- and post-rTMS. Reaction time and EMG amplitude were also measured. The peak cortical negativity for the NO-GO condition increased at FCz for all participants from pre- to post-rTMS. (3.24 μV to -16.8 μV; -1.93 to -19.6; -4.48 to -11.7). The same pattern was not noticeable in the GO condition for FCz (-16.8 to 2.28; -12.2 to 0.0285; -0.994 to -4.46). Changes in EMG activation patterns and reaction time measures were not significant. The purpose of the study was to investigate the differences in central set and motor preparation by examining changes in the cortical activity associated with these types of pre-movement activity. Observing the cortical negativity prior to the motor response can reveal information regarding motor planning preparation. Results of this analysis show that differences do exist in cortical activity associated with central set and motor preparation. Further study is required to determine whether similar differences can be observed in behavioural outcomes.

Poster #187

Faster is not more stable: speed effects on interlimb coordination and gait stability in young and older adults

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ABSTRACT

Gait speed is considered to be an important marker of function in older adults. Faster walking is characterized by decreased gait variability and better interlimb coordination, which suggest, according to dynamic principles that the stability of the locomotor pattern is increased. However, among older adults faster walkers are more likely to fall following a trip perturbation, which may suggest that stability of the locomotor pattern is decreased. Most falls in older adults occur following trips during gait and tripping perturbations are associated with longer recovery of steady-state walking in older adults. We evaluated the effect of gait speed on the responses of young and older adults to trip perturbations. Twelve young (26.3±4.4 years; 7 males) and 12 older adults (68.5±3.4 years; 8 males) walked at comfortable, 20% faster and 20% slower speeds when movement of the dominant leg was unexpectedly arrested for 250ms at 20% of swing length. In both groups, changing gait speed affected the leg strategy used immediately following perturbation such that increasing gait speed diminished the occurrence of a leg elevation (slower: 36%, comfortable: 9%, faster: 0.6% of trials) and increased that of leg lowering (slower:10%, comfortable: 48%, faster: 62% of trials). In the longer-term, increasing gait speed was associated with tighter interlimb coupling on both arm-leg pairs and between the arms, but was not associated with longer-term recovery of gait stability in either group. Older adults took longer than younger adults to recover steady-state walking at all speeds (3.36±0.6 vs. 2.89±0.5 gait cycles) and had lower inter-leg coupling. The longer duration of recovery of steady-state walking in older adults suggests that at all speeds, the stability of steady-state walking is lower in this group. This may be associated with an increased fall risk when faced with uncontrolled situations. However, an effect of aging was found only for long-term recovery of steady-state walking, suggesting the involvement of different mechanisms in short- and long-term recovery of gait stability. Increasing gait speed may improve interlimb coupling via increasing the drive to spinal central pattern generators, however the complexity of recovery of steady-state walking remained higher for older adults across gait speeds.

Poster #189

Differential learning of sequence accuracy and synchronization across six days of practice

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ABSTRACT

The acquisition of motor skills can be thought to involve several distinct behavioural components such as accuracy and synchronization. These components may show differential changes across long-term learning and consolidation. To test this hypothesis we tested participants across 6 days of learning on the Multiple Finger Sequence Task. This task requires participants to perform multiple sequences of key presses in response to visual stimuli presented on a computer screen. There are 6 blocks per day, 14 sequences per block (10 repeated; 4 random), with 13 key presses per sequence. Preliminary analyses examined performance gains within the first day of practice and consolidation gains between the last block on Day 1 and the first block on Day 2. Overall, accuracy and synchronization was greater for the repeating sequence versus random sequences. A separate set of analyses conducted for each measure found no evidence for sequence-specific, between-day consolidation on measures of accuracy or synchronization. However, a sequence-specific worsening of performance was detected for random sequences at the start of Day 2 on the synchronization measure. The results demonstrate evidence for divergent patterns of improvement between accuracy and synchronization, supporting the idea that separate components of motor learning might be regulated by different cognitive and neural mechanisms.

Poster #190

Vestibular modulation of a propriospinal-like reflex during gait

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ABSTRACT

Interactions between spinal networks, sensory feedback and supraspinal pathways ensure body balance during gait, but it is still unclear how those inputs are integrated. We investigated the vestibular control of a propriospinal-like reflex presumably involved in regulation of balance, the reflex that produces biphasic excitation of quadriceps motoneurones mediated by ankle dorsiflexor afferents (CPQ reflex, Marchand-Pauvert and Nielsen 2002). Twelve healthy subjects walked on a treadmill at 4 km/h. A sensor was put underneath the right heel to determine the stance phase of gait. EMG activity of right tibialis anterior (TA) and vastus lateralis (VL) was recorded. Biphasic facilitation in the VL in early stance (0 – 70 ms) was evoked by a test 1 ms-stimulus applied to the right common peroneal nerve (CPN). This stimulus was conditioned by galvanic vestibular stimulation (GVS; suprathreshold intensity, 3-4 mA, 200 ms), initiated at inter-stimulus interval (ISI) 40 or 150 ms prior to the CPN stimulation. GVS was applied by electrodes placed bilaterally on the mastoids (Cathode or Anode was placed ipsilaterally to the stimulated leg). In control trials, vestibular modulation of the CPQ reflex was tested during standing, while performing a tonic contraction at matched VL EMG levels and during a backward lean. GVS with Cathode ipsilaterally (ISI 40 ms) inhibited the CPQ reflex compared to control (Student's t test; p=0.01) during gait, but had no significant effect on the CPQ during leaning backward and tonic contraction. With the Anode ipsilaterally, GVS had no significant effect on the CPQ response during gait or tonic contraction but facilitated the CPQ reflex during backward lean (p=0.04). In all three conditions, the effect of GVS on the CPQ reflex paralleled the effect of GVS on background EMG of VL. At ISI=150 ms, preliminary results showed that GVS with Cathode ipsilaterally facilitated CPQ reflex during gait and leaning backward, but had no effects during tonic muscle contraction. No significant effect of GVS on background EMG of VL during gait was observed. Preliminary results suggest that the CPQ reflex is modulated by vestibulospinal tract during gait or leaning backwards when body stability is diminished.

Poster #191

Effects of unilateral and bilateral contractions of the diaphragm on posture

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ABSTRACT

Respiratory activity constantly interferes with posture. This study explored the intrinsic effects of isolated diaphragm contractions on posture. Four male and eight female healthy subjects, free from any neurological, musculo-skeletal or respiratory disease, took part in the study. An original paradigm based on bilateral and unilateral phrenic nerve stimulations and on "diaphragmatic" voluntary sniff manoeuvres was used to characterize the center gravity (CG) displacements and the respiratory movements during specific contractions of the diaphragm. CG acceleration was calculated from force plate recordings and respiratory kinematics was assessed with thoracic and abdominal sensing belts. Measurements were taken in sitting and in standing postures. CG and respiratory curves revealed that, in sitting posture, bilateral phrenic stimulation and sniff manoeuvres consistently produced an expansion of the abdomen associated with a forward peak of the CG acceleration. In standing posture, the direction of the peak was reversed and always orientated backwards. Unilateral phrenic stimulation induced an additional medial-lateral acceleration of the CG, oriented toward the non-active side while sitting but in the opposite direction while standing. These results suggest that isolated contractions of the diaphragm produce a constant disturbing pattern for a given posture, but with opposite effects between standing and sitting postures. This could be related to the different biomechanical configuration of the body in each posture, corresponding to distinct kinematic patterns of the articulated chain. In addition, the lateral component of the CG acceleration induced by unilateral diaphragm contractions could be clinically relevant in patients with hemidiaphragm paralysis.

Poster #192

Investigation on the control of the biceps brachii

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ABSTRACT

To take advantage of a myoelectric prosthesis capable of many degrees of freedom, several electromyographic (EMG) signals under voluntary control are required. In this context, we examine if the anatomical findings about the compartmental nature of the biceps brachii (BB) could be exploited to produce such set of EMGs. To determine how a voluntary movement could be associated to a compartmental activity, normal subjects produced various contractions with their right arm while EMG signals were recorded with 5 pairs of surface electrodes positioned over the short head (SH) and 5 other pairs over the long head (LH) of the BB. Amongst the experimented contractions, some consistently produced more activity in the SH while other did so in the LH. To help pinpoint within each head were activity could be located, a simple direct and inverse mathematical model was developed where the arm is represented by a finite cylinder containing an isotropic, homogeneous conductive medium and where the EMG sources are represented by dipoles oriented along the axial direction of the cylinder. The direct model which predicts the potentials distribution on the cylindrical boundary uses the equations developed by Okada equation for a single dipole. The inverse model determines the set of n dipoles which best predicts the observations. The inverse model was tested with simulated and with experimental data. Experimental data were acquired with a saline filled tank in which three dipoles where placed at known positions and the potential distributions around the tank measured with 16 equally spaced electrodes. The potential maxima around the tank, was used to obtain the number and angular position of dipoles. The inverse model was found to satisfactorily estimate the dipoles position and relative intensity when the angular separation between dipoles was sufficient large. However as dipoles angular separation would get smaller, the inverse model would fail to recover the individual position in a manner which is also a function of their radial position. Further refinement for the implementation of the inverse model are required before being able to associate with confidence a dipole position to a compartment within the SH or LH of the biceps. Meanwhile, ability to activate either of those heads is a step toward facilitating the control of a myoelectric prosthesis.

POSTER SESSION I (continued)

Theme II: Variability and Redundancy in Motor Control

Poster #11

The dominant role of arm's dynamics in the solution of kinematic redundancy during catching provides insights into Developmental Coordination Disorder (DCD)

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ABSTRACT

The present study examined factors underlying altered movements in children with DCD. Ten children with (WDCD) and nine without DCD (NDCD) used the dominant arm to catch a tennis ball above the shoulder at eye level. Initially, the arm was freely hanging down. To intercept the ball, subjects had to bring the shoulder and elbow into flexion in the parasagittal plane. Motion of the shoulder, elbow, and wrist was recorded. Net (NT), interaction (IT), gravitational (GT), and muscular torque (MT) impulse was computed at each joint. Analysis of contribution of IT, GT, and MT impulse to NT impulse revealed four distinct phases in movement control in NDCD children. In phase 1, the shoulder and elbow simultaneously accelerated into flexion and IT was suppressed by MT at each joint. This phase was, however, brief and it was quickly switched to phase 2 in which the elbow accelerated into flexion by MT, while IT accelerated the shoulder into extension. During phase 3, the shoulder was accelerated into flexion by MT, while IT accelerated the elbow into extension. Phase 4 was acceleration of both joints into extension primarily by GT. At the wrist, MT consistently compensated for IT, resulting in low, fluctuating, but primarily extending NT. Although the four-phase control strategy resulted in complex joint kinematics, it was torque-effective because it prevented suppression of IT with MT during the major portion of movement. WDCD children, however, demonstrated high inter-subject variability of joint control patterns. Some simultaneously flexed the shoulder and elbow by suppressing IT with MT at both joints. Others used the same four-phase strategy, but did not utilize IT as effectively. Some others showed inability to control for GT. The large variability in control patterns in WDCD children suggests that at this age DCD prevents development of the optimal four-phase control strategy that utilizes the arm's inter-segmental dynamics during catching.

Poster #17

Practice effects on multi-finger synergies in accurate force production tasks with graded instability

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ABSTRACT

We studied the effects of a single-session practice on multi-finger synergies during accurate force production. A special practice schedule was designed to encourage using variable patterns of finger involvement. Multi-finger synergies stabilizing the total force (F_{TOT}) were quantified within the uncontrolled manifold (UCM) hypothesis framework. Two components of variance were compared, V_{UCM} that had no effect on and V_{ORT} that affected F_{TOT}. Subjects (divided into *young one-finger*, *two-finger*, and *elderly two-finger* group) were tested prior to and after a practice session. Two weeks later young groups took part in a retention test. *One-finger* group practiced one finger at a time, while *two-finger* groups practiced index and middle fingers together. All groups improved the performance indices. *Two-finger* groups showed an increase in the index of enslaving, |E|, in contrast to the unchanged |E| in the *one-finger* group. All groups showed a decrease in V_{ORT}, while only the *two-finger* groups showed an increase in V_{UCM} leading to an increase in the total amount of variance in the space of commands to fingers and in the index of synergy stabilizing F_{TOT}. The results show that practicing elements and practicing redundant groups of elements lead to similar changes in performance accompanied by dramatically different changes in the structure of variance: a drop in V_{UCM} after the single-finger practice and an increase following the two-finger practice. These changes were retained for 2 weeks. Only the changes in performance showed significant transfer to a simpler task while changes in V_{UCM} did not. The results suggest that the central nervous system is highly adaptable to practice of tasks designed to encourage use of variable solutions in both young and elderly persons. We view the results as highly promising for future use in populations with impaired coordination characterized by low synergy indices.

Poster #20

Lower leg skin stimulation as a tool for improving postural control in the elderly

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ABSTRACT

Previous studies suggested that skin stimulation by using medical tape glued to the skin over the Achilles tendon can improve postural control in young adults. Such strategy would be valuable if helping to improve postural control in the elderly. It is widely known that elderly are in higher risk of falling and therefore, strategies to minimize the risks among these subjects are valuable for both daily life and professional care. Here we tested the effects of skin stimulation on the postural control of elderly standing barefoot. 22 subjects stood quietly barefoot on a force plate while the center of pressure was monitored during standing with and without medical tape glued to the skin over the Achilles tendon. Application of skin stimulation in the first assessment of postural control was alternated between subjects. The protocol for postural control was applied in agreement with the current literature. Our results suggested positive effects of tape stimulation for anteroposterior amplitude of center of pressure displacement, mediolateral amplitude of center of pressure displacement, and area of the ellipse for 95% of center of pressure data ($P<.05$) in the elderly. The tape would contribute to increase sensorial input for movement detection, delivering sensorial input close to the ankle. The effect can be similar those observed by applying braces and bandages, which had positive effects for postural control. However, the use of tape does not affect joint range of motion in the same extent of braces and bandages.

Poster #25

Examining lower extremity range of motion and movement variability changes due to focus of attention during landing

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ABSTRACT

The purpose of this research was to examine the effects of attentional focus (AF) instructions on landing kinematics, exploring strategies for reducing injury risk. Movement variability was used to assess neuromotor functioning and the ability of the motor system to vary internal loads. Kinematic changes during bilateral drop landings were examined via lower extremity joint range of motion (ROM) and ROM variability when using internal versus external AF. Eleven participants, (7 male, 4 female; age 23.5±13.2years; height 1.8±0.1m; mass 71.5±3.5kg) were used to examine sagittal and frontal plane ROM and ROM variability at the hip, knee, and ankle joints. Ten bilateral drop landings were performed from a 60cm plyometric box under three counterbalanced AF conditions (external, internal, control). Kinematic data were acquired using a 12-camera Vicon system (200Hz). Variability was expressed using coefficient of variation. Comparisons were made via 3x3 (Joint x AF) Mixed Model ANOVAs, with repeated measures on AF. Sagittal plane ROM differed among landing conditions, $F(2,60)=7.87$, $p=.001$, and among joints, $F(2,30)=14.56$, $p<.001$, where external and internal AF differed from the control (66.0°±23.2°, $p=.003$; 64.7°±20.2°, $p=.019$; 60.0°±19.4°, respectively), and ROM was greater at the knee (83.0°±15.8°) relative to the hip (57.4°±11.5°, $p=.001$) and ankle (50.3°±6.2, $p<.001$). Lower extremity ROM differed among joints in the frontal plane, where the knee (11.60°±4.58) exceeded the ankle (7.76°±2.76, $p=.046$) and hip joints (7.11°±3.48, $p=.016$), while ROM variability was significantly greater at the hip (39.4±13.8%), relative to the knee (22.6±10.0%, $p<.001$) and ankle (18.8±8.4%, $p<.001$). Overall, AF instructions elicited kinematic changes during landing, though differences were not observed between external and internal AF conditions. Future investigations should examine kinetic changes in landing when controlling AF, which may have implications on injury susceptibility.

Poster #28

Inferring task complexity: Moving beyond Fitts' Law

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ABSTRACT

Despite the lack of objective measures of task complexity, difficult tasks are commonly equated with complex tasks across many behaviors. Task difficulty is traditionally defined via Fitts' Law, using rigid evaluation criteria that cannot be applied to everyday actions. We propose that ambiguity between the concepts of 'difficulty' and 'complexity' in motor tasks can be resolved using techniques from the field of non-linear dynamics. Complexity of motor behavior in a Fitts-type task was compared to traditional measures of task difficulty. Our results indicate that difficult tasks are not associated with complex behaviors; rather, an inverse relationship exists between these two concepts. Use of non-linear techniques allowed for detection of behavioral differences in task performance in the presence of action errors and among neutrally co-constrained effectors not detected using traditional Fitts'-type analyses. We recommend this method be used to infer task difficulty in ecological situations that violate the Fitts'-type testing paradigm.

Theme II: Variability and Redundancy in Motor Control

Poster #31

UCM reference feedback control for joint coordination

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ABSTRACT

On the basis of the uncontrolled manifold (UCM), we propose "UCM reference feedback control" for modeling the coordination of a human redundant-joint arm. Our proposed method generates a UCM space as a control target step by step. The target UCM space is a subspace of joint angles whose variability does not affect the hand position. The joint combination in the target UCM space is then selected so as to minimize the magnitude of the joint torque and torque change. Therefore, UCM reference feedback control allows the variability in UCM space. The noise that would be reasonable in the biological motor system is assumed. Thus, our proposed method generates varied movement trajectories trial by trial. We considered a three-link arm with a shoulder, elbow, and wrist regulating a one-dimensional target of a hand. By computer simulation, we examined UCM reference feedback control and generated the following arm movements; (1) the variability of the hand at the end of motion in task-irrelevant direction was larger than that in task-relevant direction, (2) the tangential velocity of the hand was roughly bell-shaped but also had small peaks, (3) the variance which does not affect the hand position was larger than which directly affects and gradually increased from the movement start to end. To compare with these results, we conducted measurement experiments that subjects performed a one-dimensional target-tracking task. The kinematic data and quantified joint coordination were compared with the simulation data of our proposed method. As a result, subjects showed the same tendency of simulation results. These results suggest that the subjects refer to UCM space in each time step to achieve the one-dimensional target-tracking task, rather than determining and tracking unique target joint trajectories. Moreover, it is suggested that the human may control a redundant-joint arm by referring to UCM space in feedback control.

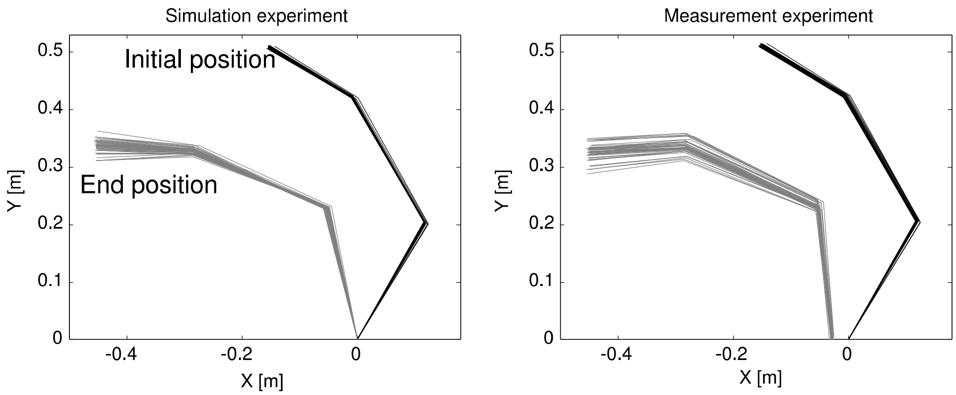

Figure 1. Arm postures generated by our UCM reference feedback control and human subject.

Poster #42

An analysis of the centre of mass trajectories during a whole body pointing movement

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ABSTRACT

Most previous studies of human motor control either focus on the postural equilibrium mechanisms or conversely on reaching movements of the focal module while restricting movement of the lower body part. Many of our actions however require the interaction of the two. The whole body pointing (WBP) task is one which involves these two elements. The aim of our study is to understand how the center of mass (CoM) is regulated during such movements. The increased height of the biped configuration would require a careful regulation of this variable for the maintenance of equilibrium while attaining the target. How does the nervous system control the horizontal and vertical aspects of the CoM trajectory? Previous studies have shown that the nervous system reduces the number of degrees of freedom of a movement through the use of synergies. Would such a strategy of using common waveforms be utilized for controlling the anterio-posterior (AP) and vertical (V) displacements of the CoM? To answer these questions, we examined the CoM trajectories of individuals pointing to a target that was placed at a distance and height that corresponded to 15% of the subject height. Our first analyses reveal that the relationship of the control between these two variables, as measured by dAP (the speed of AP displacement) and dV (the speed of vertical displacement), is one that is nonlinear. In particular, dV showed a low variability compared to dAP. This raises the possibility that the movement is organized around the vertical rather than the horizontal dimension. A study of the two trajectories showed various stereotyped transition points. Among these were the moment at which dV reaches a minimum and secondly, the moment at which the changes in the vertical direction became greater than those in the anterior posterior direction. Future studies will involve verifying if the above observations hold for WBP movements requiring a greater AP displacement and how they are altered by ageing.

Poster #44

Grip force modulation with wrist flexion and extension

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ABSTRACT

Identical muscles (FDP – flexion, EDC – extension) contribute to both grip force at the fingertips and wrist movements. We investigate the relation between grip force and wrist kinematics to examine: (1) whether grip force scales with grip strength, which was expected to vary with wrist *angle*; and (2) whether grip force can be predicted from accelerations induced during wrist flexion-extension *movement*. Nine subjects participated in the study. First, subjects maximally squeezed with all fingertips an instrumented handle in seven static wrist positions spread over their range of flexion-extension motion. Next, subjects performed quasistatic wrist flexion-extension movement with the handle. Finally, the above movement was performed cyclically at three prescribed frequencies. The finger forces and the wrist angle were recorded. Maximal grip force varied with wrist position. In contrast, for quasistatic movements, the grip force remained constant throughout the wrist range of motion. For the cyclic test, a linear regression model was used to represent the thumb and virtual finger (VF = four fingers combined) normal forces as the sum of the effects of the object's tangential and radial accelerations and an object-weight-dependent constant grip force (smaller of the thumb and VF forces). The model explained 99% of the variability in the data. The independence of the grip force from wrist position suggests that the thumb and VF are controlled with two neural variables that encode referent coordinates for each digit while accounting for changes in the position dependence of muscle forces, rather than a single neural variable like referent aperture. The regression results extend the *principle of superposition* (some complex actions can be decomposed into independently controlled elemental actions) for a movement involving significant length changes of the grip-force producing muscles.

Poster #51

The effect of target geometry on foot placement variability during adaptive locomotion in a novel stepping stone paradigm

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ABSTRACT

Bipedal locomotion over uneven terrain is a critical movement skill involving multiple instances of sequential targeting and obstacle avoidance (Warren 2007); however, the processes underlying the sequential selection and execution of foot placements onto targets have been the subject of relatively little investigation. The purpose of this study was to explore the relationship between geometric features of the walking surface and spatial patterns of foot placement variability in a novel stepping stone paradigm. Twelve healthy young adults completed a series of blocked trials in which they walked at a self-selected pace, using two interchangeable blocks as footholds for consecutive steps. All blocks were 9.5 cm high and were long (40 × 6 cm), wide (6 × 40 cm), or square (20 × 20 cm), with square targets flush to the surface additionally used as controls. The configuration was manipulated to create 6 conditions. Foot kinematics were recorded using 3D optical motion capture. It was hypothesized that a minimum intervention strategy would permit foot placement anywhere on the target, resulting in footfall variability patterns that reflect the shape of the stepping block. Relative to control, the magnitude of end–point variability was observed to expand along axes in which area was available, even though data from complementary conditions demonstrated locomotion was equally efficacious with a smaller constraint. These differences in foot placement occurred without changes in overall walking speed. Additionally, analysis of foot swing velocities demonstrated that stepping from the walkway surface onto an elevated target resulted in faster leg swing velocities. Results will be discussed as evidence of a rough terrain control strategy that maximizes the probability of a successful foot placement and minimizes the need for intervention.

Poster #53

Learning to exploit motor redundancy

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ABSTRACT

The human motor system has more dimensions along which it can vary than are strictly required by tasks in our day-to-day lives. This excess of dimensions creates redundancy in the movements and configurations of the motor system, such that there can exist multiple motor solutions for a given task. Redundancy is a source of computational complexity, but it is also an important asset that can provide stability and flexibility in action. However, how people learn to utilize available redundancy is not well understood. We have adapted an experimental paradigm designed by Mosier and colleagues (Journal of Neurophysiology, 2005) to investigate how the exploitation of motor redundancy is learned for novel motor problems. Using a full-body motion capture system, six arm joints were mapped onto the control of a cursor in a 2D virtual environment. Participants moved the cursor between target locations while passing through a fixed, centralized waypoint. The redundant nature of the motor-control problem provided opportunity for participants to vary arm posture at the waypoint depending on their point of origin and desired target. Postures at the waypoint were projected into effective and redundant space to determine if changes in the distribution of joint variability were consistent with redundancy exploitation. Posture variability at the waypoint decreased with practice, both in effective and redundant dimensions, suggesting that participants stereotyped postures regardless of starting location or intended target. We also examined whether posture at the waypoint could be used to classify participants' intended targets. Classification accuracy for intended target and point of origin was near chance. These findings suggest that the availability of motor redundancy alone may not be sufficient for developing redundancy exploitation strategies. In follow up experiments, we are exploring how factors such as task difficulty and time pressure affect redundancy exploitation.

Poster #55

Direction-Specific Learning in Stabilometer Balance Tasks

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ABSTRACT

Humans control upright posture with appropriate anticipatory postural adjustments (APAs) and automatic postural responses (APRs). Discrete muscle patterns have been observed during APAs and APRs that counteract perturbations in different directions (Aruin & Lat-ash, 1995, Henry, Fung & Horak, 1998). Varied weighting of muscle synergies may ac-count for the occurrence of different muscle patterns (Asaka, Wang, Fukushima & Latash, 2008; Torres-Oviedo & Ting, 2010). The direction-specificity of postural control is rarely considered in balance training programs (DiStefano, Clark & Padua, 2009). However, we propose that learning balance tasks is direction-specific. 36 healthy subjects (7 female, mean age: 25.4 years) accomplished 2 tasks on a stabi-lometer for 30 s in a pre- and a post-test. The stabilometer had 2 rotary axes that could be unlocked separately leading to anterior-posterior (ap) or medial-lateral (ml) sway. In one task the ap-axis was unlocked (task ap) in the other task the ml-axis was unlocked (task ml). Dependent variable is the root mean square error (RMSE) of the deviations from the horizontal. In between the tests, each of two intervention groups (IGap, IGml, n = 12) prac-ticed one of the tasks for 4 weeks twice a week (10 x 1 min). A control group (CG, n = 12) did not practice at all. Both intervention groups reduced RMSE in their practice task more than the CG, $F(1,22) = 11.61$, $p < .001$, $\eta^2_p = .35$ (IGap, task ap), $F(1,22) = 20.38$, $p < .001$, $\eta^2_p = .48$ (IGml, task ml). But they do not reduce RMSE in the other task, $F(1,22) = 0.72$; $p = .405$; $\eta^2_p = .03$ (IGap, task ml), $F(1,22) = 0.39$; $p = .539$; $\eta^2_p = .02$ (IGml, task ap). In summary, results confirm that learning balance tasks on a stabilometer is highly direc-tion-specific and no transfer is achieved to tasks with perturbations rotated through 90°. These findings should be considered in designing balance training programs in sports and clinical rehabilitation.

Poster #62

Direction dependent coarticulation in joint angles during sequential arm movements

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ABSTRACT

Originally, coarticulation had been found in speech articulatory movements, but it was also found in limb movements. Coarticulation describes an interdependency of sequential movement segments. In carry-over coarticulation a movement segment affects its successor, in anticipatory coarticulation a movement segment affects its predecessor. We examined direction dependent coarticulation both at the level of the end-effector trajectories and, given the redundancy of the system, at the level of the joint angle configurations. Right-handed participants moved a cylindrical object on a monitor-table. The movement started from one of six possible starting points that were arranged on a circle at 2, 4, 6, 8, 10, and 12 o'clock positions. In each trial, the cylindrical object was moved from the starting position to a target at the center of the circle (first movement segment) and from there to one of three possible final target positions at 2, 6, and 10 o'clock (second movement segment). To uncover coarticulation at the level of joint angle configurations, we apply an analysis of motor equivalence that is based on the concept of the uncontrolled manifold. Therefore, we decomposed the difference between joint configurations in different conditions into components that leave the position of the transported object invariant (UCM) and those that affect the position of the object (ORT). Motor equivalence is observed when this difference lies more in the UCM than in its orthogonal complement (same spatial trajectory, but moving through different joint configurations). At the level of object trajectories we rarely found direction dependent coarticulation. In contrast, at the level of the joint angle configurations, comparison of the different conditions provided clear evidence for both anticipatory and carry-over coarticulation in the form of motor equivalence. Movements that started from different initial positions and ended at the same target showed significant effects in carry-over coarticulation (investigating the second movement segment), whereas movements that came from the same initial position and aimed at different targets showed significant effects in anticipatory coarticulation (investigating the first movement segment). Overall, direction dependent coarticulation was consistently observed at the level of joint angle configurations even under conditions in which no coarticulation was visible at the level of the end-effector trajectories.

Poster #64

Interactions between grip force and hand force produced by wrist flexion

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ABSTRACT

The FDP and FPL muscles produce forces at the fingertips during gripping. FDP and FPL are the only muscles that create flexor moments at the DIP and the thumb IP joints, respectively. These muscles are also important wrist flexors. So, an interaction between tasks requiring simultaneous flexion of the wrist and the fingers is expected. We investigate the nature and degree of coupling between hand force due to wrist flexion and grip force. Eight subjects were tested in two conditions. 1) Subjects held a handle with the 5 fingertips and produced 5 levels of hand force while ignoring the grip force magnitude. 2) Subjects produced 6 levels (10 to 60% of grip MVC + wrist MVC) of combined grip and hand forces. The 1st condition shows an increase in grip force with the hand force resulting in a significant correlation (~ 0.3) between the two forces (upper left panel). Interestingly, hand force production leads to a change in grip force, but not vice-versa. We call this phenomenon 'serial enslaving'. The data from the 2nd condition is subjected to the UCM analysis. The VUCM increases logarithmically and VORT increases exponentially with the specified task force (upper right panel). The synergy index is always positive ($\Delta V > 1.5$) indicating that the two forces co-vary such that variability in either have minimal effects on the task despite the enslaving. The grip force associated with serial enslaving is subtracted from the total grip force to obtain $F_{TRUE\text{-}GRIP}$ (plotted against the hand force in the lower panels). Some subjects show close to zero $F_{TRUE\text{-}GRIP}$ (left lower panel); they rely entirely on serial enslaving and produce the total force by modulating the hand force only. Other subjects modulate both hand force and $F_{TRUE\text{-}GRIP}$ to perform the task (right lower panel). In both cases, hand force and $F_{TRUE\text{-}GRIP}$ show negative co-variation across trials. We conclude that the apparently involuntary mechanism of serial enslaving can contribute to the creation of synergies.

Poster #65

Structured variability in muscle activation patterns during cycling at different muscular demands

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ABSTRACT

Certain theories suggest that movement variability reflects dynamic control rather than random noise. Movement variability is often discussed in terms of the uncontrolled manifold hypothesis or the minimal intervention principle. Support for these theories is primarily based on kinematic data or quasi-static EMG. There is limited insight about the variability during dynamic muscle activation at different performance levels lacking a direct linkage to the physiology of muscular control mechanisms. Therefore, the purpose of this study was to characterize the variability of muscle activation during cycling at two constant load conditions. EMG was recorded from 7 leg muscles for 15 male subjects while cycling at 150W and 300W. Seventy consecutive cycles were analyzed in each condition. EMG was subdivided into nine frequency bands (19-330 Hz). A Principal Component Analysis was used to decompose the EMG into eigenvectors (EV) sorted by their explained variance. Principal Activation Components (PAC) were calculated by projecting the EMG data onto the EVs. The relative variability (RV) of all PACs was calculated and normalized to the magnitude of the PAC. To explain 90% of the variance, 20 and 10 PACs were needed for the 150W and 300W condition, respectively. Both conditions could be split into low variability and high variability PACs (Figure 1). The variability for the 300W condition was significantly lower compared to the 150 W condition ($p < 0.05$) for both the low variability and high variability components (Figure 1). We showed that dynamic muscle activity is characterized by structured variability. It seems that muscle activation components are more tightly controlled as power output/performance is increased. The LV PACs represented the dominant movement components in both conditions and were characterized by the activation of the quadriceps muscle, which is known to be essential for the power production in cycling. This result may be interpreted in support of the minimum intervention principle that task-oriented movement components show less variability compared to redundant components. Specifically, this could be interpreted as a transition into a regime of necessary muscles, or it could be interpreted as the transition into a regime where the task more precisely specifies the muscle coordination pattern. Future studies should investigate if this transition is biomechanically dictated or neurally chosen.

Poster #67

Coordination stability in the golf swing with changing task constraints

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ABSTRACT

Conventional methods for analyzing movement quality in sports such as golf, often involve comparisons to a reference movement model. This method overlooks current motor control insights which suggest that deviations from the reference model for a particular variable may be compensated for by another variable. Furthermore, the conventional approach ignores the ability of the individual to meet the ever-changing demands of the task. The method presented in the current study uses a visualization, based on SOMs, of coordination stability to investigate how expert golfers adapt their movements to meet changing task constraints. Eight male expert golfers participated in the study. Average 5-iron (d_5) and 6-iron (d_6) distances were determined for each participant. The half-club distance (d_h) was defined as $(d_5-d_6)/2$. Each participant played ten shots to the following target distances: d_5+d_h, d_5, d_5-d_h, d_6+d_h, d_6 and d_6-d_h. The average distance for each club was considered to be the 'comfortable' swing for the respective participant. Therefore, modifying the target distance by half a club represented a perturbation to their, presumably, stable coordination pattern. Data were collected using a Polhemus Liberty tracking system. Pelvis, thorax, head, lead upper-arm and lead hand angular rotations about the *x*-, *y*- and *z*-axes were analyzed. The SOM visualization of coordination stability showed that players with better distance control recruited qualitatively different movement patterns for at least one of the distances, which suggests multistability. Players with less sensitive distance control did not show different coordination patterns, rather a single less stable pattern marked by higher variability compared to the stable patterns shown by the better golfers. The strategies for modifying coordination pattern were unique to each participant. The findings of the current study suggest a larger repertoire of coordination patterns for golfers with more precise distance control.

Poster #89

Visual-motor tracking depends on the temporal location of visual information about properties of the target path and the target path regularity

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ABSTRACT

In visual-motor tracking, information about past, current, and future properties of a target path can be available but the relative contribution of these information categories to tracking performance is not well understood. The aim of the current study was to investigate the role of visual information pertaining to past and future states of the target path in guiding isometric tracking performance as a function of the irregularity of the target path. Presence of past information of the pathway did not improve performance of force tracking for any target path. Presence of future information improved performance only for the semi-regular target path. Additionally, other measures of force output and target path regularity (cross correlation, ApEn) influenced performance on only the semi-regular target path. Tracking of a target path with temporal characteristics between regular and random seems to allow the most flexibility, allowing visual information to play a greater role in behavior.

Poster #105

The need of standardized assessment of motor performance in preschool children

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ABSTRACT

Normal motor abilities and development are prerequisites for the daily activities of preschool children. Motor activities are considered to have an impact on their later perceptual, cognitive and social development, thus, normative data on motor development are necessary. The aim of this cross-sectional study is to provide normative data for gross and fine motor tasks using the Zurich Neuromotor Assessment (ZNA) enabling to detect children who are talented as well as those who are in need of further support. Typically developing children between 3 and 5 years of age (N = 101; 48 boys) were enrolled and tested in using a modified version of the ZNA. Quantification of performance was achieved for all tasks (i.e., time was measured in motor tasks, or otherwise, a 5 point scale was introduced). The modelling approach summarized the data with a linear age effect and an additive gender term, while incorporating informative missing data in the normative values. Normative data for adaptive motor tasks, pure motor tasks, static and dynamic balance were calculated with centile curves and expected ordinal scores. Nearly all tasks showed significant age effects, while gender was significant only for stringing beads and hopping on one leg. These results indicate that timed performance and ordinal scales of neuromotor tasks can be reliably measured in preschool children and are characterized by developmental change and high inter-individual variability. Norms are presented which include data of the non-achievers. Norms for this age group are important because the preschool period is considered to be a vulnerable period for the developing motor system. Only with normative data one is able to distinguish normal motor from abnormal motor behaviour and to detect progress in motor abilities in preschool children after interventions.

Poster #118

Effects of Muscle Vibration on Multi-finger Interaction and Coordination

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ABSTRACT

The purpose of this study was to investigate the effects of vibration on multi-finger interaction and coordination. We hypothesized that unintended force production by non-instructed fingers (enslaving) would increase with muscle vibration while synergy indices during steady-state force production would drop. The framework of the uncontrolled manifold hypothesis was used to quantify indices of multi-finger synergies stabilizing total force during steady-state force production and anticipatory changes in these indices (anticipatory synergy adjustments, ASAs) in preparation to a quick force pulse production with and without hand muscle vibration. The dominant hands of eight healthy right-handed subjects were tested under three conditions: no vibration, vibration of the palmar surface of the hand, and vibration of the forearm applied over the flexor muscles. There were no significant effects of vibration on maximal voluntary force. The magnitude of enslaving was larger during vibration of the hand compared to the other two conditions. During steady-state force production, indices of force-stabilizing synergies were lower during vibration of the hand. Prior to the force pulse initiation, the synergy index started to drop earlier and over a larger magnitude without vibration than in either vibration condition. Effects of vibration on enslaving and synergy index may be due to diffuse reflex effects of the induced afferent activity on alpha-motoneuronal pools innervating the extrinsic flexor compartments. The smaller synergy indices and ASAs may reflect supraspinal effects of the vibration-induced afferent activity, in particular its interactions with trans-thalamic loops.

Poster #122

Developmental Changes of Whole-body Synergy in Squat-to-Stand Movement

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ABSTRACT

Synergistic control of multiple body segments is essential for whole body movements. The purpose of this study was to investigate developmental changes in motor control during squat-to-stand (STS) movements with different bases of support (BOS). Thirty subjects participated in this study, and ten of each age group was formed, six years old (116.2 4.3 cm, 23.1 3.9 kg), ten years old (138.7 7.2 cm, 35.8 10.3 kg), and twenty years old (23 1.6 years old, 164 11.4 cm, 60.8 12.0 kg). Movement ABC was used to make sure that children were typically developing in terms of motor function (six years old: 77.5±18.6%; ten years old: 73.9±12.7 %). There were 9 BOS conditions that were achieved by varying foot distance in the medial-lateral direction. The BOS conditions included 0%, 20%, 40%, 60%, 80%, 100%, 120%, 140%, and 160% of shoulder width. 160% was the longest, and 0% was the narrowest condition which two feet put together. Each subject performed STS movement 10 times consecutively for each BOS. A motion capture system (Qualysis, Sävebalden, Sweden) captured the kinematic data of each body segment at 120 Hz. The whole body center of mass (COM) position was computed from all body segments. The UCM analysis was used to quantify the multi-segment variability and was performed in three dimensions, anterior-posterior, medial-lateral, and vertical. Elementary variables were the position of the each segmental COM and the performance variable was the position of the whole body COM. The position vector has three directions, anterior-posterior, medial-lateral and vertical. Two-way repeated measures ANOVA was performed for statistical analysis. The results showed that VUCM and VORT were greater in 6-year olds than 10-year olds and adults ($p<.05$) and ρV was greater in adults than children ($p<.05$). Significant differences across BOS were shown in only medial-lateralML direction. In general, the 0% BOS had the smallest VUCM, the largest VORT, and the smallest ρV ($p<.05$). We concluded that (1) the motor synergy of the squat-to-stand task increased from 6 years of age to adult and (2) the smallest BOS condition seems to be hard to control for synergistic actions of body segments.

Theme II: Variability and Redundancy in Motor Control

Poster #130

Timing of executing a whole-body interceptive movement, consisting of multiple movement components

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ABSTRACT

Initiation of an interceptive movement was examined by focusing on a single parameter that characterized the task movement, such as, elbow or knee joint extension for swinging a bat to hit a falling ball (e.g., Katsumata & Russell 2011; Zago et al., 2005) or jumping up to punch it (Lee et al, et.al.1983; Michael, et al.2001). However, interceptive movements as in many sports performances consist of multiple movement phases. For instance, hitting a baseball is achieved by the combination of stepping a front foot forward, rotating a trunk, shifting the center of gravity forward, moving arms to handle the bat. Therefore, identifying the motion events primarily relevant to timing the task movement with respect to the upcoming ball-bat contact is important to understand the timing of interceptive performances. 9 male college students with baseball experience participated in the experiment. To focus exclusively on the timing modulation of the swing action, the task movement needs to be achieved without spatial adjustment of bat trajectory against the moving ball. To this end, a coincidence timing task paradigm was adopted: a ball was dropped from one of three different heights, and batters swung a bat so as to synchronize the swing onset with respect to the moment of a ball landing on the ground, rather than the moment of the bat trajectory passing through the interception point (5 trails per each height, randomly ordered). By this task design, it was attempted to elicit the batter's decision process about the movement initiation. An optical motion capture system was used to analyze the movements of a ball, a bat, and better's lower/upper extremities and trunk rotation, and two force plates for GRF by each of front and rear foot.
The analysis of timing of each action event with respect to the time-to-contact (TC: the time until the ball touching down on the ground), the following timing parameters were not statistically different from the zero-TC: the moment of GRF application by the rear foot, the front foot touching down on the ground, the hand rotation onset for swinging the bat, the moment of the 10% maximum bat-swing speed, and the stepped foot GRF application for the trunk rotation. The timing variability across the sequence of action events revealed such that the closer to the zero-TC the action events, the lower the variability ($r=.67$, $p<.005$). These indicate that these action events were implicated with the batter's reaction to initiate the swing movement. Furthermore, the compensatory timing relationships amongst those action events were observed such that the relatively earlier/later onset of a particular action event was followed by longer/shorter duration toward the subsequent event. These results emphasize on the importance of identifying the key movement components for timing a task performance and investigating the temporal organization of the multiple action events for understanding the timing mechanism of whole-body performances.

Poster #132

Effects of experimental muscle pain on force variability during task-related and three directional isometric force task

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ABSTRACT

Experimentally muscle pain induces changes in the distribution of muscle activity and affects the muscle coordination. The force steadiness is impaired during muscle pain in the task-related force direction as well as in the tangential directions. In addition, pain lead to a mismatch between the sense of effort and motor output during contractions. However, little is known about the pain effects on the force components when task-related or three-dimensional force matching task are required. The aim of this study was to quantify changes in the force variability during task-related and three-dimensional force task during acute muscle pain. Twelve right-handed healthy volunteers participated in the experiment. Three-dimensional force signals were acquired during isometric elbow flexion at 5%, 15%, and 30% of the maximum voluntary contraction (MVC). The force components were represented by a circle on a computer screen, and a moving square was used for the visual target. Subjects were asked to match the main direction of the contraction during the task-related (1D) or all the force components during the three-dimensional (3D) force matching tasks. Isotonic and hypertonic saline injections were randomly injected into the biceps brachii muscle. The coefficient of variation (CV) was used to analyze the variability on the task-related force direction. The total excursion of the center of pressure (CoP) was used to quantify the variability on the tangential force directions. Complexity of the force was measured using sample entropy (SEn). Three-way repeated measures ANOVA with factors level of contraction, pain/control, and time were performed for the CV, the CoP, and the SEn of each component of the force. In the tangential forces, no significant effects were found for the 3D matching tasks. The ANOVA of parameters from the 1D task showed a significant interaction between level of contraction, pain/control, and time ($P<0.05$). Post-hoc analysis of the interaction showed that the total excursion of the center of pressure for the 1D task was higher during pain compared with the control session ($P<0.05$). In the task-related force, no significant effects were found for the CV during the three-dimensional task or for the task-related task. Finally, the ANOVA analysis of sample entropy showed a significant interaction between pain/control and time ($P<0.05$) in the main direction of the contraction, showing that the sample entropy was higher compare with the control session during muscle pain in the 1D tasks ($P<0.001$). The variability of the tangential forces and the complexity of the task-related force were increased during experimental muscle pain only for the task-related contractions. This could be associated with a lack of visual information that yields to an undesirable motor control situation increasing the force variability.

Poster #136

Error amplification improves performance by reducing neuromotor noise

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ABSTRACT

Performance improvement in learning a new task typically proceeds by iteratively decreasing errors. In the presence of noise error correction gains should be small to prevent overcorrection/instability; if too small, performance improvement will be slow. As gain and noise are interrelated, an alternative route to performance improvement is decreasing subjects' intrinsic noise. This study used a virtual throwing task to explore the mechanisms underlying performance improvement with error amplification. Three hypotheses were tested: H1: Error amplification elicits larger performance improvements than veridical feedback. H2: Error amplification elicits changes in both gain and intrinsic noise. H3: Added extrinsic noise leads to reduction in intrinsic noise and thereby even greater improvement. Subjects manipulated a lever arm to throw a virtual ball to hit a target as accurately as possible. Subjects practiced "skittles" for 3 days without amplification (240 throws/day); on 3 more days, visual feedback was altered showing amplified errors. 3 groups received deterministic error amplification (DEA) with amplification factors of 1.5, 2.0, and 2.5. Three additional groups received the same DEA, but with added noise (stochastic error amplification; SEA). A control group received veridical error information. To estimate each subject's feedback gain and noise, performance was modeled as a simple error-updating system with two independent noise sources. Relative noise magnitudes were defined as: K=1 only execution noise; K=0 only planning noise. System identification estimated the feedback gain B, noise variance N, and K for each subject on Day 3 and 6 (before and with manipulation). The optimal B was calculated for each subject as the one giving minimum average error. Results showed that both DEA and SEA groups decreased error from Day 3 to 6 more than controls (H1). Neither DEA nor SEA groups showed significant changes in B compared to controls (counter H2). Non-systematic changes in K were observed for all groups, except DEA-2.5. At the end of Day 3, most DEA and SEA groups had gains above the optimal gain. Since K and N changed across practice, the optimal B changed; the effect of error amplification was to raise subjects' gains even farther from optimal. This alone would have made performance worse, however this was offset by significant reductions in noise N for both DEA and SEA at amplifications >1.5, consistent with H2. Counter to H3, there was no additional performance benefit with added extrinsic noise. The results showed that error amplification improved task performance, in agreement with previous reports. Error amplification caused correction gains to increase beyond the optimal value that would give the least average error, but this was offset by decreased intrinsic noise. Thus, error amplification did not improve performance by changing subjects' feedback gains, but by decreasing the overall magnitude of neuromotor noise.

Poster #137

Effects of additional weight on posture-movement adaptations to repetitive arm motion-induced fatigue

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ABSTRACT

Fatigue and extra body weight are both risk factors of injuries by falls since they have both been shown to affect postural stability. In addition to the well-known effects of trunk and lower limb fatigue on postural stability, we have previously shown that posture-movement changes occur with upper limb repetitive motion-induced fatigue. These include lateral body shifts and increased trunk range of motion (ROM) along with the arm movement. These strategies facilitate the arm movement sub-task and as such, reflect task-specific fatigue adaptation strategies. However, they may also jeopardize postural stability and represent a threat to equilibrium. In situations where equilibrium is already challenged, such as with extra body weight, less risky strategies in terms of postural threat may be developed with repetitive motion-induced fatigue. Nineteen participants performed two sessions of a repetitive pointing task (RPT) while standing, in normal conditions and with an added load of 20% body weight (Belt), until reaching fatigue (Borg CR-10 scale rating of 8). Whole-body kinematic, kinetic and EMG characteristics were recorded and the first and last minutes of the RPT (Time) were analyzed. Mean average positions and ROMs were calculated over 10 consecutive repetitive movements, as well as the coefficient of variation (CoV) to assess movement-to-movement variability. There was no difference in time to fatigue between the two weight conditions. Muscle activity significantly increased with time in the anterior deltoid (18.84 ± 28.24 %), biceps (35.72 ± 32.65 %) and upper trapezius (23.99 ± 24.03 %), confirming that muscle fatigue was induced. There were significant Belt by Time interaction effects on peak mediolateral center of pressure (CoP) velocity ($F(1,16) = 5.09$, $p = 0.038$) and on the reaching shoulder's mean vertical position ($F(1,13) = 8.4$, $p = 0.012$), both lower and less affected by fatigue with the extra body weight. A significant Belt by Time interaction effect was also found in CoP displacement CoV, with higher variability with fatigue, and more so with additional weight ($F(1,17) = 6.71$, $p = 0.019$). With fatigue, lateral shifts where seen in the reaching shoulder and elbow joints towards the non-reaching side, and increases in ROMs were found at most joints but not at the body's center of mass (CoM). Increased variability was seen with both fatigue and extra weight in most kinematic parameters, with the most notable fatigue and belt effects on CoM characteristics. Findings suggest that fatigue and extra weight induce significant posture and movement changes but that their interactions only affect a few parameters, mostly those related to CoM and CoP characteristics. The few interaction effects, combined with the absence of difference in time to fatigue between the weight conditions, suggest that the system is mostly able to deal with fatigue and with 20% additional body weight using parallel control mechanisms.

Poster #140

Strategies in rhythmic object manipulation: predictability or chaos

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ABSTRACT

Movements such as reaching in dynamic environments or manipulating objects with internal degrees of freedom have been shown to be optimal in terms of task kinematics, kinetics, energetics or accuracy. These criteria were formulated for discrete tasks, not explicitly addressing the characteristics of object dynamics in continuous rhythmic interactions. We hypothesize that in rhythmic interactive movements the nonlinearity of the object's dynamics plays a dominant role in shaping the performer's strategy; i.e., humans avoid unpredictable or chaotic solutions and favor control strategies that afford predictable interactions with the object. This hypothesis was tested using a virtual object manipulation task, simulating carrying a cup of coffee (non-linear cart-and-pendulum dynamics), performed via a robot manipulandum. In Experiment 1, subjects (n=10) oscillated the cup between two target locations (distance=10cm) at a metronome pace of 1Hz (40 trials, 45s each). Thus, the movement amplitude and frequency were specified; however, subjects could choose different relative phases between the ball and cup. In Experiment 2, subjects (n=8) could choose their movement amplitude and relative phase, while producing 1Hz back-and-forth movements; hence, solutions defined a 2-dimensional space. The result space of ball-and-cup kinematics (assuming sinusoidal cup trajectories) was defined by amplitude, frequency, and relative phase between ball and cup. Inverse dynamics simulations showed that realization of task in different regions of the result space corresponds to strategies that differ in "effort" (mean squared force per cycle) and predictability. Predictability was quantified by an index based on cycle-by-cycle variance of force, and by mutual information between the cup kinematics and the applied force; both provided matching measures of predictability. Results of Exp. 1 showed that with practice subjects changed their strategies from in-phase to anti-phase, which corresponded to moving into high-predictability regions of the result space. However, this change was coincident with effort minimization. Exp. 2 was designed to dissociate solutions with predictability and minimal effort. The simulations highlighted that complex tasks may have solutions with differing levels of chaotic or unpredictable behavior. Experimental results showed that with practice the movement amplitude, effort level and predictability index increased, i.e., the subjects chose regions in the 2D solution space with higher predictability, even though these regions were associated with higher effort, a measure typically expected to be minimized in human movements. Our findings supported the hypothesis that humans prefer to maximize dynamic predictability when rhythmically manipulating complex objects. The quantification of predictability expresses that humans seek solutions where force and kinematics are synchronized into a repeatable pattern, yielding overall rhythmic performance.

Poster #145

Functional architectures using Structured Flows on Manifolds

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ABSTRACT

We outline a theoretical framework for understanding complex sequential sensorimotor behavior that is consistent with the deeply rooted notion in the life sciences that such behavior comes about by sewing together basic behavioral units in sequence. Basic units are conceptualized as *Structured Flows on Manifolds* (*SFM*), that is, temporarily existing low-dimensional dynamical objects emerging from high-dimensional systems. Theorems from dynamical system theory allow for the unambiguous classification of behavioral classes as represented by *SFM*s, and thus provide a means to define and identify basic units. The ensemble of *SFM*s available to an individual defines his or her dynamical repertoire. We briefly review experimental evidence that has identified a few basic elements prominent in probably each (healthy) individual's repertoire. Complex sequential behavior requires the involvement of a (typically high-dimensional) dynamics operating at time scale slower than the ones associated with the elements in the dynamical repertoire. At any given time, the slow dynamics temporarily favors the dominance of one element of the repertoire (competition) in a sequential fashion thereby sewing together *SFM*s and generating complex behavior. The time-scale separation between the elements of the repertoire and the slow dynamics define a time-scale hierarchy; their ensemble defines a functional architecture. We illustrate the approach via a functional architecture for handwriting as proof of concept. In discussing the implications of this framework for sensorimotor control, we in particular (i) point out the view of basic units of behavior in terms of temporally existent dynamical objects (*SFM*s) rather than hard-wired neural structures, (ii) hypothesize that motor control is geared towards creating structured flows rather than trajectories, (iii) show how functional architectures widens the notion of motor equivalence, and (iv) cuts through traditional divisions of motor planning and execution, and (v) link our behavioral framework to converging results in resting state research focusing on dynamical repertoires.

Poster #148

Differentiation of pointing movements using a feature value method

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ABSTRACT

Movements such as pointing or reaching are performed on a daily basis but the performance or control strategies for these movements may differ between individuals. The question arises if it is possible to distinguish between different strategies based on the kinematics of each person. Previous research has shown the efficiency of the PCA and cluster analysis to systematically detect emotion displayed in gait. In this study we applied a PCA on feature vectors derived from the kinematic data of a pointing task. We hypothesized that this feature vector method would allow for the recognition of individual subjects and conditions. Participants sat on a chair with two targets placed in front of them and were instructed to perform sequences of discrete movements from the left target to the right target and vice versa at two velocities (natural vs. maximum speed) resulting in a total of four conditions. A 250e ten-camera motion capture system was used to record the resulting arm movements at a rate of 250 Hz (Natural Point Inc., Corvallis, USA). The subjects wore twenty-three markers from which ten upper limb joint angles were calculated. To analyze the movements, we calculated a feature vector of the model. The feature vector of a data-set is computed as the auto-correlation matrix for each component of the data-set and the obtained feature vector provides information of the clustering possibility of the training data-set. Consequently, information is provided on the possibility to discriminate data-sets from one another. Applied to individual kinematic data, differences and similarities of motion data-sets can be visualized. The higher the similarity of the data sets, the closer the clusters are in the principal component space. To analyze the specific feature vector of the pointing movements, we used a PCA and computed the feature vectors that were affected by the experimental conditions. Across all experimental conditions, the clusters were clearly separated.

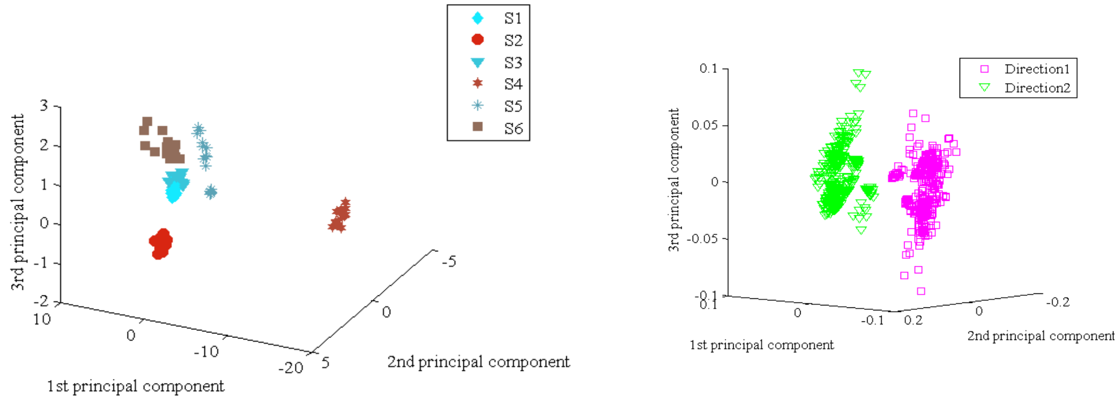

Figure 1. The measured means of the feature space on the (A) subjects and (B) directions are separated into clusters using the first three principal components.

In other words, the feature vectors of the kinematic motion capture data showed that every movement and subject had particular, distinguishable characteristics. The results showed that the pointing motion between subjects and movement directions differ and that the clusters are visibly separated from one another (see Figure 1). Regarding the efficiency of the feature space separation, a clear separation between the experimental conditions and subjects was achieved. It has been shown that the clusters in the feature space are separated, indicating that each feature of the pointing movements are well extracted. We can conclude that it is possible to recognize specific movement patterns without using classification methods like support vector machines. This study was supported by the Japan Society for the Promotion of Science (JSPS/FF1/391 ID No. PE 12509).

Poster #149

Physiological finger tremor size reflects altered mechanical properties of muscle resulting from changes in neural control

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ABSTRACT

It is impossible to hold your fingers perfectly still or to move them completely smoothly; there will always be some tremor present. Human physiological finger tremor comprises two main frequency components, one around 8-12 Hz and one usually around 20 Hz. Recent studies suggest that these peaks may be produced by a single mechanism rather than the two distinct mechanisms (mechano-reflex and central) that have been previously regarded as necessary. We have shown that the complete range of tremor frequencies can be recreated by entirely random drive to the musculature. The frequency of the tremor that is produced depends on the filtering properties of skeletal muscle which alters with the size of the movement (muscle thixotropy). Here we systematically examine the relationship between the size of neural input to the finger and the frequency of the tremor that is observed. Fifteen healthy subjects (23.7 ± 9.9 yr, 12 male) volunteered to participate in the study. Physiological tremor of the splinted middle finger was measured using a miniature accelerometer. EMG was recorded from the extensor digitorum communis muscle (m. EDC). A retroflective laser sensor recorded finger position, which was displayed on a pc in front of the subject. The subject's task was to move the finger vertically in flexion / extension so its position was aligned with a target that was also displayed on the pc. The target existed of a sinusoidal chirp signal, which ranged symmetrically from 0 Hz to 0.05 Hz to 0 Hz over 100 s, and a static posture 10 s before and after the chirp. During the static posture the finger was in a comfortable mid extension-flexion position and the extent of flexion / extension was approximately 30 deg (See Fig 1, top). The required angular velocity of the finger ranged from 0 to 3 deg/s, which subjectively was very slow. Each subject was asked to repeat the 120 sec trial 10 times. For each trial, a wavelet analysis was performed on acceleration and rectified EMG and wavelets were averaged across trials and participants. We correlated the size of acceleration and EMG with each other and with the finger position and speed (Pearson's correlation). As expected there was a correlation between EMG and acceleration but this was relatively weak ($r^2 = 0.19$). The size of EMG increased when the vertical position of the finger was higher ($r^2 = 0.85$) (Fig 1, top), whereas acceleration size seemed to correlate with the speed of the finger ($r^2 = 0.73$) (Fig 1, bottom). We suggest that the size of physiological finger tremor may be mainly determined by movement-related (thixotropic) mechanical changes of the muscles. When the speed of the movement increases, more muscle tissue will be in motion. This causes a progressive drop in muscular stiffness, which has been associated with an increase in tremor size. Transition from posture to movement gives the nervous system an inherently less stable load to control.

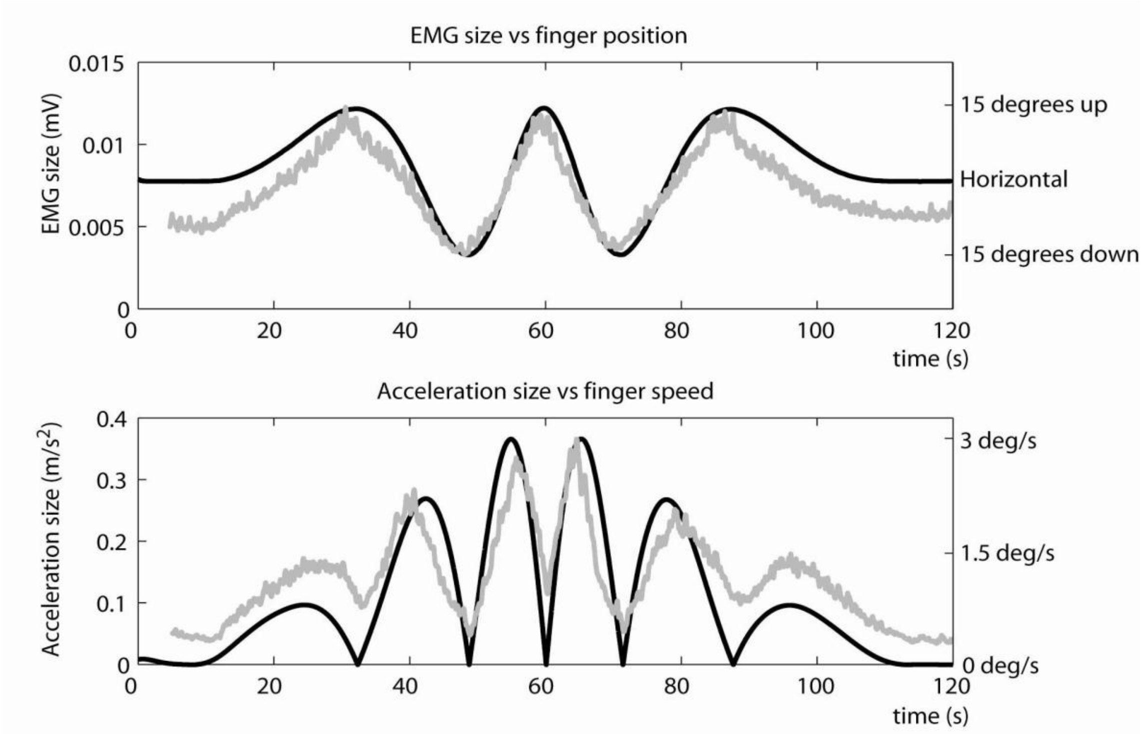

Figure 1. Top graph: EMG size (grey) is adjusted with finger position (black). Bottom graph: Acceleration size (grey) is adjusted with finger speed (black).

Poster #161

Influence of load and speed on inter-segmental coordination and stride-to-stride variability of gradient walking

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ABSTRACT

Walking with a loaded backpack is often done by military, athletes and students. In combination with walking on a gradient or slope, this may lead to pain and risk of falls. Changes in walking speed reflect systematic alterations in limb temporal parameters, kinematics and kinetics. Rotation of the pelvis contributes to the stride length (SL). However, loading results in a smaller contribution of pelvis rotation and, consequently, the stride frequency (SF) increases to maintain gait speed. The present study investigated the changes in CoV of stride parameters, trunk and pelvis range of motion with and without load (25% bm) at different gait speeds (1, 2, 3, 4 and 5 km/h) during gradient walking (9º). Specifically the CoV of SL, SF and Trunk Range of Motion (TRM), Shoulder Range of Motion (SRM) and Pelvis Range of Motion (PRM) were analyzed using 3-D videogrammetry (50 Hz). The results show that, with or without load, the lowest SL and SF variability occur at intermediate speeds. At lower speeds there was a greater variability on TRM. The SRM and PRM presented minor variability in loaded walking than the unloaded walking. On the other hand, the load inversely affected the CoV of TRM, where there was greater variability in the loaded situation ($p < 0.05$). This outcome could be related with systems perturbations (gradient and backpack load), where there is a greater variability due to a less consistent motor pattern (inexperienced subjects in the task), especially in relation to the preparatory stage of the motor programming. Backpack influences, mostly, the weight of the trunk, therefore, individuals without experience in load and inclination walking, show greater spatiotemporal variability at slower speeds. Besides, the motor control of the upper segments seems to be more sensitive to load effect while the speed affects mainly the spatiotemporal variability.

Poster #163

Learning to exploit dynamic stability in a motor task

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ABSTRACT

While rhythmically bouncing a ball with a racket is a seemingly simple task, it requires a high level of perceptually-guided coordination to succeed. The present study examined how humans learn this sensorimotor skill, based on modeling the task with a dynamical model of the racket and ball interactions. In the experimental task, subjects manipulated a real table tennis racket to rhythmically bounce a virtual ball to a target line in a 2D virtual environment. Stability analyses of the model showed that dynamical stability is indicated when the racket impacts the ball during the decelerating portion of the racket's upward motion (Schaal et al. 1996; Dijkstra et al. 2004). Dynamically stable performance implies that small errors converge back to stable performance without requiring active corrections. However, considering a single bounce only, it is more energy-effective to impact the ball at maximum velocity. We hypothesized that subjects initially optimize for the single bounce, but then learn to exploit the dynamically stable strategy that can be performed with fewer error corrections (H1). To examine whether learning the dynamically stable solution can be adopted faster, we added a time-dependent perturbation to the racket velocity at contact: negative acceleration at contact adds a positive perturbation to racket velocity and thereby achieves higher ball amplitudes and vice versa. Thus, less effort was required to perform the task accurately with negative acceleration at contact. We hypothesized that subjects learn to exploit dynamic stability faster by altering contact stability (H2). Six subjects practiced the virtual ball bouncing task over 28 trials with each trial lasting 40 seconds. A second group of six subjects practiced the task with altered contact stability for 25 trials, followed by 3 trials under normal conditions. The objective in both conditions was to hit the ball rhythmically and accurately to the target height. Results showed that over practice, both groups learned to minimize error between maximum ball height and the target line, as well as to exploit dynamic stability by showing negative accelerations of the racket at contact (H1). The group practicing with altered contact stability, however, learned to hit the ball with decelerating racket trajectory at a faster rate (H2). Importantly, this transferred to performance under normal conditions. They also showed a statistically significant more positive perturbation added racket velocity over practice. Thus the required effort for accurate performance was minimized as predicted when acceleration at contact becomes increasingly negative. These results show that humans can learn coordinative behavior by exploiting dynamic stability in a way that also minimizes effort.

Poster #167

Persistent decrease in neuromotor noise by manipulating error tolerance

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ABSTRACT

Prior work of Sternad and colleagues showed that in a redundant task with a manifold of equivalent solutions performance variability can be parsed into three components: Tolerance, Noise and Covariation. With practice, all three components decrease, but Noise remains highest and least accessible to improvement. Humans seek solutions where neuromotor noise or errors have minimal effect on task achievement. Such error-tolerant strategies are co-determined by the task and the individual: If neuromotor noise is high, subjects need error-tolerant solutions; if tolerance is low, neuromotor noise needs to be reduced. This study manipulated error tolerance in a motor task via visual information, with the goal to induce individuals to reduce their neuromotor noise. We hypothesized that visual information signaling low error tolerance leads to lower noise levels at a faster rate than under normal practice conditions (H1). Using a virtual throwing task, subjects performed a single-joint rotation about the elbow and released a virtual ball that traversed a concentric force field to hit a target. Subjects saw the ball's trajectory and its distance from the target center. If the ball trajectory passed within a threshold around the target, the subject received a binary success signal. The size of threshold determined the degree of error tolerance: smaller threshold signaled less error tolerance. Experiment 1: Two groups of subjects practiced skittles over 11 daily sessions (240 trials each). The control group practiced with no threshold; the experimental group practiced with a threshold of 1.1cm. Results showed that subjects with error tolerance information reduced Noise faster, but not to a lower level. Experiment 2: To test whether noise levels could be reduced, a third group practiced with threshold that was manipulated in three stages: in stage-1 (3 sessions) the threshold was 1.1cm, in stage-2 (3 sessions) the threshold was .65cm, in stage-3 (5 sessions) the initial threshold of 1.1cm was reinstated. Based on simulations using a state space model with two noise sources, we hypothesized that when error tolerance is decreased or increased during practice, subjects respectively decrease or increase their noise to maintain success (H2). Results showed that when error tolerance was lowered in stage-2, subjects reduced their noise faster and to lower levels as hypothesized (H1). When error tolerance was increased in stage-3, subjects did not increase their noise level, counter to H2. Rather, they retained their lowered sensorimotor noise. Preliminary data the same threshold conditions repeated under different target configurations further support the generalization of our findings. These results have implications for rehabilitation as signal detection and control processes in the sensorimotor system may be enhanced by manipulating visual feedback based on error tolerance.

Poster #173

Postural task constraints and bimanual rhythmic coordination

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ABSTRACT

Most research on rhythmic bimanual coordination has occurred with the participants in a seated position. Many activities of daily living, however, require the interaction of standing postural and manual tasks. The purpose of this experiment was to investigate the effects of standing postural tasks of varying difficulty on bimanual rhythmic movement coordination and variability. Expert drummers (N=8) were recruited from the University of Massachusetts Drumline, and were asked to perform an anti-phase coordination task in one of four postures : sitting, standing with two feet on a solid surface, standing on one foot on a solid surface, and standing on one foot on an air filled balance disk (Disk). Drum stick kinematic data was recorded at 240 Hz (Oqus, Qualysis, Sweden). Drum stick marker position and time data were used to calculate discrete relative phase (DRP) and DRP variability (SD), which were used as outcome measure to assess the effects of the different postural conditions on movement coordination. Participants were instructed to focus on rhythmic accuracy and temporal consistency (sitting trials), or to keep as balanced and upright as possible while remaining as rhythmically accurate and temporally consistent as possible (standing trials). A total of 84 movement cycles (84 for left and right) were analyzed for each subject. A paired t-test was used to compare the most challenging postural condition (Disk) to the other three conditions (sitting and standing on two and one leg on solid surface). The statistical analysis demonstrated that there were no significant differences in the average DRP across all postural conditions ($p >. 23$). Postural condition, however, did have an impact on the variability of DRP. Significantly greater DRP variability was found in the Disk compared to the sitting ($p = .0107$) and the standing on two feet (solid surface) ($p =. 005$) conditions. Interestingly there was no difference when the Disk was compared to the standing on one foot on a solid surface condition ($p =. 4765$), showing no difference between the two more difficult postures. Based on these results we conclude that postural constraints affect the focal task, not by changing the average DRP, but the variability in the DRP signal. These results are in line with previous work done on anti-phase bi-manual rhythmic tasks insofar that increasing variability of the rhythm is inherently linked with increasingly difficult task constraints, here imposed by more difficult postural demands.

Poster #176

Development of Leg Joint Synergy during Walking with Growth

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ABSTRACT

We have reported that adults exploit leg joint synergy during walking in order to adjust the toe position especially at some critical points to stabilize walking, e.g., during the second double support phase and at the moment when the toe passes the lowest position during leg swing. How does such leg joint synergy develop with growth? In this study, we analyzed the variance of leg joint trajectories during walking on a treadmill of eight-year-old children by the UCM analysis and examined how hip, knee, and ankle joints form synergy so as to suppress the variance of the toe position relative to the hip position. Strong joint synergy that adjusts the toe position was observed in the second double support phase and middle of swing phase both in adult and child subjects, however, the change in the degree of joint synergy of adult subjects were clearer and showed more ups and downs than the change in the child subjects. This result shows that the separation of different control strategies, one that utilizes joint synergy and the other that does not, develops for different moments of walking with growth. Some studies have shown that eight-year-old children show adult walking pattern. However, our results suggest that the leg joint synergy of eight-year-old children is not matured and in development.

Poster #194

Characterizing the effects of sum of sine stimuli on the linearity and non-linearities of the compensatory eye movement system

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ABSTRACT

Compensatory eye movements (CEM) maintain a stable image on the retina by using visual and vestibular input to drive eye movements that cancel movements of the head and the surroundings, thereby preventing retinal slip. The optokinetic reflex (OKR, moving visual field and fixed head) and the vestibular ocular reflex (VOR, head movement in the dark) compensate for low and high velocity stimuli, respectively, and are complementary in the CEM system. The VOR system is generally considered and modelled as a linear system and should therefore satisfy the superposition and homogeneity principles. The OKR system is known to be highly non-linear. We recorded eye movements in response to sinusoidal stimulation to test whether any combination of applied stimuli would output eye movements that satisfy the superposition principle. To this end, we tested the linearity of the VOR and OKR systems by using non-harmonic Sum of Sine stimuli (SoS) in C57Bl6 mice as well as single sine (SS) stimuli. We collected behavioural data in four different CEM conditions: VOR, OKR, visually-enhanced VOR (VVOR, head movement in the light), and suppressed VOR (sVOR, head movement and visual field movement cancel each other). We used stimuli containing frequencies of 0.6hz, 0.8hz, 1.0hz, 1.9hz and amplitudes of 1deg or 2degs. SoS combinations used were 0.6/0.8hz; 0.6/1.0hz; 0.8/1.0hz; 1.0/1.9hz with each frequency at 1 or 2 degrees or both at 1 or 2 degrees. We compared the gains and phases of the SS stimuli with the SoS stimuli. Suppression of gain was seen in the OKR during SoS and some gain enhancement was seen in VOR and SVOR conditions indicating non-linearities in the CEM system. The results are compatible with the notion of a prediction signal during SS stimulation that enhances the behavioural response and thus increases the gain of the OKR. To further investigate the source of the non-linearities in CEM we also collected behavioural and electrophysiological data from the flocculus using SS and SoS stimuli. Finally, the State Predicting Feedback Control (SPFC) model of Frens & Donchin (2009) was tested in the four CEM conditions and it reproduced accurately the gain and phase of the behavioural responses along with the main properties of the CEM system for single sine stimuli. The SPFC model also correctly predicted non-linearities in OKR responses at higher frequencies and amplitudes. Combining the SoS stimuli data and the behavioural results of the SPFC model, we can begin to unravel the non-linearities of the CEM system.

POSTER SESSION II:

Theme III: Equilibrium-Point Control and Perception-Action Coupling

Poster #6

Effect of additional sensory information on mobility of fallers and non-fallers elderly

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ABSTRACT

The number of people over 60 years of age is projected to double in the next 20 years. It has been suggested that elderly people present reduced ability to control their postual balance, which may predispose them to increased risk of falling. Studies have investigated the manipulation of sensory information in the control postural strategy using the soft touch on a hard and stationary surface, and found a reduction significant in the body oscillation compared with the situation without touch, suggesting that sensory information and motor action are closely related to the task of keeping the body in a certain position. The objective of this study was to investigate the effect of additional sensory information in mobility in elderly with and without a history of falls. 8 patients with a history of falls (FG) and 7 patients without a history of falls (NFG) were evaluated. The mobility was evaluated using the *Time Up and Go* test (TUG). The additional sensory information was made with an elastic infrapatellar bandage placed bilaterally. The comparison was made by unpaired *t* test, with $p \leq 0.05$. The mean of age was not significantly different (70.7±4.1 years old to FG and 71.3±5.4 years old to NFG). The mean of mobility was 17.3±3.0 s without bandage and 15.6±2.9 with bandage to fallers elderly ($p = 0.002$). No significant difference was found in the non-fallers elderly with or without the placement of elastic compression ($p = 0.52$). The comparison of FG and NFG with the bandage showed a significance difference ($p = 0{,}004$). The data showed that the manipulation of sensory information can improve mobility in the elderly fallers, suggesting improvement in postural balance. Funded by FAPESP (2011/07548-6).

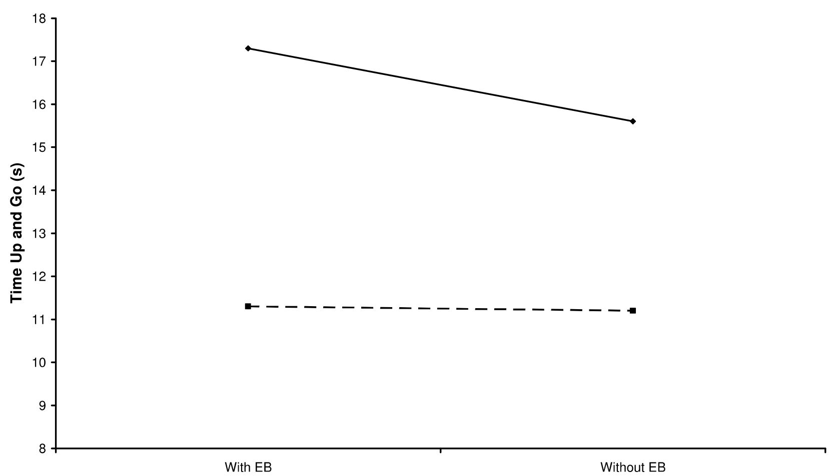

Figure 1. Mean of values of Time Up and Go (seconds) of fallers (—) e non-fallers elderly (---). EB: elastic bandage.

Poster #9

Impact of forearm fatigue on the postural response to an externally initiated, predictable perturbation

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ABSTRACT

Central fatigue has been hypothesized to impact motor performance but its specific impact on postural control is not clear. The aim of this study was to examine the impact of central fatigue on the anticipatory postural response to steady-state oscillations of the support platform. Fatigue was induced in the forearm muscles by a bi-lateral handgrip contraction. These muscles were not involved in the postural task and so any postural changes found post-fatigue were attributed to changes within the central nervous system, i.e. central fatigue, as opposed to fatigue within the muscle fibres. Measures of postural stability, including the center of mass (COM) and center of pressure (COP) displacement and muscle activity, were quantified before the forearm muscle fatigue protocol and throughout a ten-minute recovery period. Immediately after fatigue, participants activated postural muscles earlier and decreased their COP displacement in anticipation of the platform oscillations. These values returned to baseline as the quantifiable central fatigue recovered despite the lingering peripheral feedback from the fatigued non-postural muscles. The findings from this study suggest that central fatigue, created by the fatiguing forearm contraction, modified the postural strategy used to maintain stability. This is the first study to clearly demonstrate that central fatigue impacts dynamic postural control. The results should be considered during the development and implementation of rehabilitation programs in populations already at risk for falling.

Poster #10

Stance-related changes in postural control during hand pushing

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ABSTRACT

A number of work and leisure activities that involve voluntarily pushing are performed while standing asymmetrically. The goal of the study was to investigate anticipatory (APAs) and compensatory (CPAs) postural control during pushing performed while standing in the symmetrical and asymmetrical stance. Ten healthy volunteers stood with feet parallel and in staggered stance with right foot forward or backward and were instructed to use both the hands to push the handle of the attached to the ceiling pendulum Bilateral EMG activity of the trunk and leg muscles and the center of pressure (COP) displacements in the anterior-posterior and medial-lateral directions were recorded and analyzed during the APAs and CPAs. There were differences in the EMG activity and the COP displacement between the parallel and the staggered stance. In particular, the COP displacements in the medial-lateral direction were significantly larger in the staggered stance than in the parallel stance. Moreover, in the staggered stance, the APAs in the thigh muscles of the backward leg were significantly larger and the CPAs were smaller than in the forward leg. Moreover, generation of substantial APAs was always resulted in smaller CPAs regardless of the type of the stance. There was no difference in the EMG activity of the trunk and shank muscles between the stance conditions during both, APAs and CPAs. The study outcome suggests the importance of stance characteristics in control of posture during pushing.

Poster #18

Effects of sleep deprivation on sensorimotor coupling adaptation in night shift workers

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ABSTRACT

Sleep deprivation has been shown to cause detrimental effects on postural control. Difficulties maintaining conscious effort in the task of controlling posture as well as impaired ability to select appropriate sensory information from the environment to conduct motor actions have been suggested as possible explanations. The purpose of this study was to investigate the effects of sleep deprivation on sensorimotor coupling adaptation due to the intention to resist to visual surrounding manipulation in night shift workers. Six night shift workers were tested after being approximately 21 hours awake and compared to six control subjects who slept normally the night before the tests. All participants performed seven 60-sec trials in which they remained upright, as still as possible, inside a moving room that was oscillating with velocity of 0.6 cm/s, amplitude of 0.9 cm and 0.2 Hz frequency. Before the fourth trial, participants were informed that the room was moving and asked to resist to its movement. Lower gain values revealed that control subjects reduced the influence of room movement on their postural responses after being informed about the room movement and asked to resist to it. However, the same decreased coupling to visual information was not observed for the sleep-deprived subjects, whose gain values remained unchanged. Although night shift workers frequently spend large periods without sleep, these subjects failed to engage attention and conscious efforts on the task of reduce the influence of room movement on body sway. Twenty-one hours of wakefulness were sufficient to compromise participants' ability to select relevant information from the environment to conduct their motor actions appropriately, which might have significant implications regarding risks of traffic or work-related accidents.

Poster #27

The construction of subjective judgments about one's own movements: a transcranial magnetic stimulation study

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ABSTRACT

Subjective judgments regarding one's own movements can be misleading (e.g., third arm illusion, illusion of self-motion). The psychological processes underlying the way subjective impression of self-motion is built remain largely unknown. In order to investigate these processes, subjective judgments with respect to small involuntary movements were collected. The movements were provoked by transcranial magnetic stimulation (TMS) pulses applied over the motor cortex (M1). These movements were recorded by electromyography (EMG) and motion capture. Sixty TMS pulses were delivered to 20 right-handed participants (10 females) (Mean age: 23.25, S.D.: 2.92). Following each pulse, the participants were asked to answer four questions in regard to: (1) The specificity of the movement of their right index finger; (2) The control they felt they had on this movement; (3) Whether they felt they were the agent behind this movement; (4) The amplitude of the movements. Participants also had to complete the body awareness scale (BAS; Sheilds, 1989) and the Mindfulness Attention Awareness Scale (MAAS; Brown & Ryan, 2003). A hierarchical regression was conducted to predict which variables were involved in the construction of subjective judgments. Objective data (EMG activity and distance of the movement) were entered in the first step ($r = .609$; $p < .001$), while the data related to the other questions were entered in the second step. Only control brought a significant contribution to the total model ($r = .771$; $p < .001$). A large proportion of the variance of the subjective judgment of amplitude could be explained by the model, which relied strongly on objective cues and was also altered by other subjective impressions. The capacity to adequately use objective cues seems to be linked with mindfulness. Further studies are needed to confirm this conclusion. Differences between participants will also be discussed.

Poster #29

Age-related changes in the dynamics of movement patterns: insights from discrete Fitts' task

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ABSTRACT

The present study aimed to explore how the dynamics underlying the adaptation to increasing task difficulty reorganizes in advanced age. Fitts' paradigm was used to explore movement reorganization in terms of patterns of coordination between acceleration and deceleration phases. Recent findings suggested that a transition between two dynamic regimes occur when task difficulty (ID) is manipulated via target width (Huys et al. 2010; Sleimen-Malkoun et al. 2012). The question remains of whether such transition is observed in older adults and what is its functional significance with respect to adaptation capabilities of the aging neurobehavioral system. Therefore, we explored age-related changes in movement patterns used to perform a discrete Fitts' task across 10 difficulty levels. Two patterns were observed when ID increased, which corresponded to either the lengthening of both acceleration (AT) and deceleration (DT) times (co-variation pattern), or only DT (dissociation pattern). Analysis of discontinuity in ID-AT relation showed that young participants switched from the co-variation to the dissociation pattern at 6.5 bits. Pattern switching was accompanied by concomitant changes in the variability of AT/DT ratio. In older adults however, only the dissociation pattern was used regardless of the ID. Hence, neither an abrupt discontinuity in ID-AT relation nor significant changes in the variability of AT/DT ratio were observed. In addition, though the dissociation pattern was adaptive in young adults for high accuracy constraints, in older adults, it compromised task performance for lower IDs. Age-related adaptations observed in discrete Fitts' task were not comparable to those observed in bimanual coordination tasks (Temprado et al. 2010), wherein elderly possessed a multi-stable repertoire of intrinsic patterns. In Fitts' task, the repertoire of possible movement organization patterns, which can be temporarily assembled as a result of available muscular, cognitive and sensorimotor resources under task dependent constraints, seems to be reduced, thereby decreasing the elderly's adaptability to task constraints.

Poster #47

Influence of an error-related auditory feedback on the adaptation to a visuo-manual perturbation

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ABSTRACT

One important question concerning sensorimotor learning is the ability of the CNS to use supplementary sensory information to enhance learning or adaptation. We propose to answer this question in the framework of a very classical adaptation experiment with an error-related auditory feedback. Two groups of respectively 18 and 17 healthy adults participated in a pointing experiment involving the adaptation to a visuo-manual perturbation. The perturbation was a 60° rotation introduced between the motor space (a graphic tablet) and the visual space. Participants had to point to eight different targets as fast as possible (16 repetition of blocks of 8 targets). There was no perturbation during the first three and the last three blocks. The second group received an auditory feedback: it was a pure tone, which amplitude was related to the distance to the target and the panoramic related to the horizontal relative position of the hand and the target. We computed for each trajectory its length, its duration, its mean and maximal velocity and its number of velocity peaks. We also calculated the global characteristics of the adaptation curve (amount of adaptation, size of the perturbation, size of the after-effect). The results demonstrated that all the participants except three adapted significantly to the perturbation. However, none of the statistical tests we carried out showed a significant effect of the presence of the auditory feedback. Our conclusion is that the presence of this error-related supplementary auditory feedback had no significant influence on the adaptation of the participants. This can be explained by the dominance of vision and the small size of the effect, embodied in the variability of the data. This study is pursued to test the influence of other types of auditory feedback, for instance a concurrent knowledge of performance feedback related to the kinematics of the movements (ANR Legos project).

Poster #58

Interval Timing Judgements Altered by Motor Activity

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ABSTRACT

Interval timing involves the judgement of durations ranging from 0.5 seconds to some minutes. Interestingly, some of the brain areas known to be involved in interval timing are also important in motor activity. The most important of these may be the basal ganglia (Coull et al, 2011) and the presupplementary and supplementary motor areas (Mita et al. 2009). This raises the possibility that motor acts accompanying interval timing judgment, might influence the latter process and especially its learning. In order to test this hypothesis, we carried out interval timing tests following different types of training, some of which included motor acts. The pre and post training tasks consisted of a button press upon presentation of a visual stimulus, appearing at fixed intervals. Improvements in reaction times were taken as indicating improvements in interval judgment. Training consisted of asking the subjects to respond to visual presentations of the stimulus with the intervals to be used in the test phase. Depending on the group to which the subject belonged, the individual was asked to either 1) point with a whole body movement 2) point with the arm from a sitting position 3) imagine a whole body pointing 4) simply watch the stimulus presentation. Subjects undergoing training in interval estimation using motor activity showed significant improvements on these judgments compared to individuals who had not. Interestingly, although the gains, were not as important, the group using motor imagery also showed significant improvements in the interval judgments over the group only watching the stimulus presentations. Control tests were carried out in order to ensure that the improvements obtained with motor training could not simply be attributed to an improved attention or facilitation in sensory motor coordination for this group. The results of this test indicate that motor activity can improve interval timing judgments.

Poster #70

Effect of sensorimotor training using additional sensory information on balance

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ABSTRACT

Sensorimotor training is often used in physical therapy to prevent sport injuries or to treat specific problems of neuromuscular system. For example, after ACL lesion, the postural control is compromised, mainly, in those more challenging situations such as single leg stance. One possible explanation is that the afferent information from the injured leg is diminished and the feedback mechanism is affected. In situation like this, the sensorimotor training and the use of additional sensory information could be able to enhance the performance of the neuromuscular system. The purpose of this study was to examine the effect of a sensorimotor training programme on balance, with and without the use of the additional sensory information. Thirty healthy individuals participated on this study, divided in three groups: control group (CG), experimental group without additional sensory information (EG), and experimental group with additional sensory information (EGI). Participants realized a single leg stance task, without vision, on force plate, in two sensory conditions: 1) normal information condition — without additional sensory information; and 2) additional sensory information condition — provided by an infrapatellar strap. Three trials of 30 seconds were performed in each sensory condition. From plate force were calculated the mean sway amplitude of the center of pressure in both directions (AP and ML). Participants from experimental groups realized ten sessions of a sensorimotor training programme using balance board, with or without additional sensory information, according the determined group. Participants from experimental groups showed reduction of mean sway amplitude ($p < 0.05$). Furthermore, the results showed difference between experimental groups ($p < 0.05$). In conclusion, the sensorimotor training programme used on this study improves the balance of healthy individuals and these effects are maximized with the use of additional sensory information. Acknowledgements: This work was supported by the FAPEMIG – Process APQ-00783-09.

Poster #72

Eliminating the preparation cost for bimanual asymmetric movements

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ABSTRACT

Research has shown that in a choice reaction time task, bimanual asymmetric reaches take longer to prepare than symmetric reaches (Heuer and Klein, 2006). This asymmetric cost may be related to the simultaneous preparation of two different amplitudes. We replicated these results in a previous experiment and showed that the cost can be eliminated by temporally separating the preparation of each arm (Blinch et al, 2012). This was done by precuing the movement of one arm. The precue likely encouraged preprogramming, which eliminated the asymmetric cost. However, it was unclear as to exactly what was preprogrammed; did preprogramming occur for the precued and the non-precued movements? The purpose of this experiment was to probe the process of preprogramming with the start-react effect (reviewed by Carlsen et al, 2012). Participants performed symmetric and asymmetric bimanual reaches to short- and long-distance targets in simple, 2-choice, and one precue 2-choice conditions. Control trials involved an 86 dB imperative stimulus tone; this was replaced on startle trials with a 120 dB tone. Control reaction times showed that the asymmetric cost in the 2-choice task was eliminated with a precue. Trajectories on startle trials were examined to determine what movement was preprogrammed for each arm. In 2-choice, all participants made accurate symmetric movements on startle trials. Since the movement was unknown in advance, participants may have preprogrammed movements in the general direction of the targets (forward). These forward movements may have been released by the startle tone, with target selection occurring during the movement. In one precue 2-choice, the precued arm always went to the correct target, whereas the non-precued arm showed reach errors. It would appear, therefore, that the precue led to correct and accurate preprogramming of the cued arm. The non-precued arm, in contrast, moved in the general direction of the targets as a default strategy.

Poster #79

Visuomotor processing and grip and load force coordination in dyslexic children

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ABSTRACT

Developmental dyslexia is characterized by deficits in literacy acquisition, despite adequate intelligence level and educational opportunities. Besides showing reading and writing difficulties, dyslexic children also present sensorimotor deficits. Researchers have suggested that such deficits are caused by a mild cerebellar dysfunction. As the cerebellum has an important role in visuomotor processing as well as in grip force (GF) and load force (LF) coordination during object manipulation, we examine both phenomena in dyslexic children during a manipulation task. Ten dyslexic and 10 non-dyslexic children (9-13 years-old) were asked to grasp a vertically oriented and fixed instrumented handle using the tip of all digits of the dominant hand and continuously pull the handle up and relax to match a sequence of sine waves presented in two different frequencies (0.75Hz and 1.5Hz). The sine waves and the current vertical component of LF were displayed in a computer monitor placed in front of the participants. The task performance (i.e. visuomotor processing) was assessed by the root mean square error (RMSE). The GF-LF coordination was determined by the grip to load ratio (GF/LF), GF gain and offset, and maximum cross-correlation coefficient (r_max) and time lag. Results revealed better indices of GF-LF coordination in 0.75Hz than in 1.5Hz. However, no main effect of group and group by frequency interaction were revealed, except for r_max. Namely, while dyslexic and non-dyslexic children presented a similar r_max in the 0.75Hz condition, the dyslexic children showed a lower r_max than non-dyslexic children in the 1.5Hz condition. These findings indicate that this group of dyslexic children have no deficit in visuomotor processing but, have changes in GF-LF coupling when task become more complex. Lower r_max in dyslexic children in 1.5Hz condition could be a signal of a mild cerebellar dysfunction supporting the cerebellar hypothesis regarding the cause of dyslexia.

Poster #80

Age-related differences on static balance, berg balance scale and timed up and go test

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ABSTRACT

The worldwide population is progressively aging, with an expected increase in demand for long-term care. Impaired balance has a significant negative impact on mobility and functional independence in older adults. However, regular physical activity has been associated with a decreased risk of functional limitations in older people. Therefore, the purpose of this study was to investigate the static and functional balance and agility in sedentary younger adults and physically active older adults. Forty individuals participated on this study, divided in two groups: younger adult group (n = 21); and older adult group (n = 19). Participants were submitted to three evaluations: 1) static balance: double leg stance task on force plate, in two visual conditions: with and without vision. Three trials of 30 seconds were performed in each visual condition and the total displacement of the center of pressure was calculated; 2) Functional balance: measured by the Berg Balance Scale (BBS); and, 3) Agility: performed by the Timed Up and Go test (TUG). The main findings indicated that functional balance and agility were better in younger adults than older adults. The results demonstrated significant differences in values of Berg Balance Scale and TUG test between groups ($p < 0.05$). No significant difference was observed in the total displacement of the center of pressure between groups ($p > 0.05$). However, the older adults demonstrated higher total displacement of the center of pressure without vision ($p < 0.05$). In conclusion, the physically active older adults evaluated on this study showed lower performance of balance and agility in comparison with sedentary younger adults. The findings suggest that functional balance and agility are compromised in the older age ranges, despite the beneficial effects of regular physical activity. Acknowledgements: This work was supported by PUC Minas Research Foundation (FIP – PUC Minas) – Process #2011/6605-S2.

Poster #86

Spatiotemporal parameters of gait during stair negotiation in people with Parkinson's disease: Relationship to disease severity, use of the handrail and difficulty self-perception to go up and down the stair

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ABSTRACT

This study aimed to investigate the relationship among the spatiotemporal parameters of gait in different phases to go up and down the stair, the severity of PD, the use or not of the handrail and the difficulty self-perception to go up and down the stair. Sixteen PD patients (9 men/7 women) participated in this study. A four steps stair was used. Kinematics of gait during stair ascent and descent were obtained by OPTOTRAK system. Disease severity was assessed by the UPDRS scale. We recorded the number of times that participants used the handrail. At the end of each trial we asked the participants about their difficulty self-perception to go up and down the stair. Correlation of stairs ascent variables: approach phase – step double support duration and UPDRS motor section (rs=0,605); step velocity and difficulty self-perception (rs= -0,516). Transition phase – step duration with difficulty self-perception (rs=0,502) and with handrail using (rs=0,506); step double support duration and UPDRS motor section (rs=0,588). Stairs descent variables: initial phase – step single support duration with facility/difficulty self-perception (rs=0,627) and with handrail using (rs=0,589). Transition phase – handrail using with step length (rs= -0,724); step duration (rs=0,533); step double support duration (rs=0,520); and step velocity (rs= -0,615). Finalized phase – step velocity with difficulty self-perception (rs= -0,507). During stair descent the handrail using was related to several gait parameters, suggesting that the participants use the handrail to ensure safety to stair descent. Disease severity was related only to gait variables from stairs ascent and the difficulty self-perception to go up and down showed relationship with some gait parameters especially in initial and transition phases, suggesting these phases were more critical to the participants.

Poster #87

Postural control in children with visual impairment in the age groups 5 – 11 years of age – Partial Analysis

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ABSTRACT

The consequences of visual impairment in motor control have been studied with the analysis of static posture, but some of the results were not reliable or reproducible. Besides, only the effects of the blindness and not some degree of visual impairment instead of total blindness different degrees of visual impairment were checked. We studied the postural control of children with some degrees of visual impairment. Twenty-nine children with normal vision (NV group; 55.17% girls) and 17 with visual impairment (VI group; 41.17% girls), aged between 5 and 11 years, remained in an upright position in two conditions: eyes opened (EO) or closed (EC). The body oscillation was calculated in anteroposterior and mediolateral directions from the variables (velocity, amplitude, frequency and area) of oscillation of body center of pressure (COP) using a force platform (EMG System, Brazil*)*. Our partial results showed that children with VI had no significant differences of COP oscillations with the EO or the EC when compared to children with NV, suggesting that the visual impairment may not have a negative effect on the balance during the maintenance of static posture. In children with NV, the anteroposterior and mediolateral amplitude of oscillation of the COP increased with the EC ($p < 0,05$) comparing to the EO condition, corroborating the use of visual feedback to allow less variability of the dislocations of the COP. Surprisingly, in children with VI the mediolateral velocity and amplitude of oscillation of the COP were significantly lower with the EC when compared to the EO condition. These results seem to indicate that the children with VI may not depend on visual information as children with NV. Therefore, children with VI may have developed the ability to maintain the upright position without visual feedback, which may be related to their ability to direct, to value and to manage somatic and vestibular afferents more efficiently than the children with NV.

Poster #98

Corticospinal control of elbow movement

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ABSTRACT

According to a dominant theory, the motor cortex is directly involved in pre-programming motor outcome in terms of movement trajectories and EMG patterns (motor commands to muscles). In contrast, the equilibrium point theory suggests that the motor cortex sets and resets the spatial thresholds, i.e., the positions of body segments at which muscles and reflexes begin to act. Thereby, motor commands emerge without pre-programming, depending on the difference between the actual and the threshold position of the body segments. To choose between these two theories of motor control, we investigated corticospinal influences associated with voluntary changes in elbow joint angle in healthy individuals using transcranial magnetic stimulation (TMS) of the brain site projecting to motoneurons of elbow muscles. In order to minimize the influence of motoneuronal excitability on the evaluation of corticospinal influences, motor evoked potentials (MEPs) elicited by TMS were obtained during the EMG silent period produced by a brief muscle shortening prior to the TMS pulse. MEPs were obtained at a flexion and an extension elbow angle actively established by subjects. MEPs were recorded from 2 elbow flexors (biceps and brachioradialis) and 2 extensors (medial and lateral heads of triceps). Flexor MEP amplitude was bigger at the elbow flexion position and extensor MEP was bigger at the extension position (reciprocal pattern). A similar difference in corticospinal influences at the 2 elbow positions was often preserved when the tonic activity of elbow muscles was equalized by compensating the passive muscle forces at the two positions with a torque motor. Thus, corticospinal influences and EMG activity were de-correlated. It is concluded that the corticospinal system resets the spatial thresholds for muscle activation when segments move from one position to another without pre-determining the magnitude of motor commands to muscles. Results complement other demonstrations that the motor cortex sets spatial thresholds at which muscles and reflexes begin to act, rather than directly pre-determining movement trajectories and motor commands. Results imply that deficits in spatial threshold control may underlie different neurological motor problems (e.g., weakness, spasticity and limitations in interjoint coordination). Supported by NSERC (Canada). Post-doctoral fellowship of NI was supported by a team grant from l'Équipe de Recherche en Réadaptation Sensori-Motrice, CIHR (Canada).

Poster #103

Proprioceptive properties of torso cutaneous information and postural control

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ABSTRACT

In the absence of visual information, body spatial representation is primarily attributed to muscle proprioception. However, cutaneous information from the skin around distal joints has a significant proprioceptive role with vectorial properties. We showed that localized alterations of cutaneous information from torso areas result in reorganization of the standing posture and directional displacements of the torso consistent with vibration-induced skin stretch responses. Hence, we hypothesised that for the cutaneous system overlaying the abdominal area around the torso, directional encoding should present summation properties. This work quantified the direction and magnitude of postural shifts elicited by vibrotactile stimulation in ten young healthy adults. In the absence of any other instruction, participants were asked to maintain an upright posture (eyes closed). Six vibrators were positioned on the torso in contact with the skin over the left and right external oblique (EO), internal oblique (IO), and erector spinae (ES) muscles (anatomical reference only) at the L4/L5 vertebrae level. Postural changes, defined by body segment attitude in space, were analysed as a function of three stimulation conditions: vibration (250Hz) at single locations (SV), simultaneous vibration at two locations (CoV), and simultaneous vibration at all locations (AlV). Conditions and stimulation locations were randomized. SV stimulations induced significant directional torso inclinations, except when applied to either EO locations. Co-vibration of skin areas over both IO and both ES locations induced significant forward and backward inclinations of the torso in the mid-sagittal plane, respectively, which correspond to the angular summations of the respective individual vectors, but with a magnitude equal to the magnitude measured for the corresponding SVs. However, CoV over the left IO and ES or right IO and ES did not produce torso inclinations, which also correspond to the angular summation of the individual directional effects and the absence of torso lateral flexion during skin vibration over the EOs. The absence of effect from the AlV condition is also in agreement with a summation of all individual effects. Hence, symmetric homonymous (both IO or ES) and heteronymous (left or right IO-ES) stimulations resulted in "*directional*" summations of the respective individual effects, but not in "*vectorial*" summations since the magnitude of torso inclinations induced by single and corresponding co-vibration conditions were identical. This indicates that the sensory message elicited by a given vibration magnitude corresponds to a skin stretch of a certain magnitude, which is associated with a torso inclination of a specific magnitude. Therefore quasi-identical vibrations applied to symmetric locations elicit tactile information corresponding to similar torso inclination magnitudes. Our results are in agreement with the encoding properties of proprioceptive receptors.

Poster #106

Action-perception coupling in kinesthesia: a new approach

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ABSTRACT

It has been recognized that the position sense (PS) is derived from proprioceptive, cutaneous and articular signals integrated with central control signals underlying motor actions. The nature of this integration remained unclear because of controversies in the understanding of how actions are controlled. Recent studies have confirmed that motor actions are controlled by the setting and resetting of the referent position (R) of body segments at which commands to muscles emerge, without pre-programming, depending on the difference between the actual and referent position of body segments. It is suggested that the R, rather than a copy of the motor commands to muscles, is the central component of PS. Thereby afferent signals deliver information about the deviation (P) of body segments from the referent position. The R and P are combined at a central level to determine the actual position (Q) of body segments: Q=R+P. This rule explains not only PS in different motor tasks but also kinesthetic illusions, including the phantom limb phenomenon. The additive structure of the PS rule was confirmed in the present study. While testing PS in involuntary and voluntary movements against different loads, we also confirmed that PS is independent of motor commands or sense of effort. The PS rule explains why subjects can be unaware of arm motion resulting from tendon vibration − no-motion illusion found in our study. This study advances the understanding of how motor actions are controlled and perceived. It also provides novel insights into action-perception coupling in kinesthesia.

Poster #117

Rotation axes changes during a throwing task

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ABSTRACT

Throwing objects in everyday life varies from sportive activities to casual actions like throwing a balled up paper into the trash. In sports such as baseball, team handball or American football overarm throwing takes an important part in the game. It has been shown that during different arm configurations involving flexion-extension of the elbow, most often a separation between the axis of minimal inertia (e3), the shoulder-center of mass axis (SH-CM) and the shoulder-elbow axis (SH-EL) of the whole arm occurs. The use of e3 is more efficient and requires less intervention of the CNS while the use of SH-EL requires more skill and higher joint torques. The question arises if during an overarm throwing task a change of the rotation axis occurs. Participants were standing and instructed to perform two sequences of 10 maximal velocity overarm throws with a tennis ball to a target in 5 meters distance. A T160, eight-camera motion capture system was used to record the resulting arm movements at a rate of 250 Hz (Vicon Oxford, UK). The subjects wore 35 markers and 7 upper limb joint angles were analyzed. Three different throwing phases were considered, the preparation phase, the cocking and the Acceleration – Follow through phase. Three particular vectors were calculated, the arm center of mass position (SH-CM) and inertia tensor at the shoulder joint center (SH-e3) and the shoulder elbow axis (SH-EL) in the local frames respectively. To analyze the variability of the 3D angular displacements of the rotation axes, we used the framework of the Minimum Inertia resistance principle and computed rotation axes of the arm that were affected. For the period of the preparation phase no tendency of a preferred rotation axis could be uncovered. The variability of the SH-EL (0.78 ± 0.24 rad) did not differ ($p > .05$) from the variability of the SH-CM (0.77 ± 0.17 rad) and e3 (0.76 ± 0.16 rad) during the preparation phase. During the Cocking phase the change of rotation axis occurs and the variability of the SH-EL (0.43±0.13 rad) was significantly ($p < .05$) larger than the variability of the e3 (0.32±0.08 rad). In contrast post hoc tests could not confirm differences between SH-CM (0.33 ± 0.09) & SH-e3, so subjects rotate their arm in a compromise of both axes. During the acceleration and follow through phase the variability of the SH-EL (0.52±0.19) was significantly (p.<.05) smaller than the variability of the SH-CM (0.80±0.21) & SH-E3 (0.82±0.23 rad).

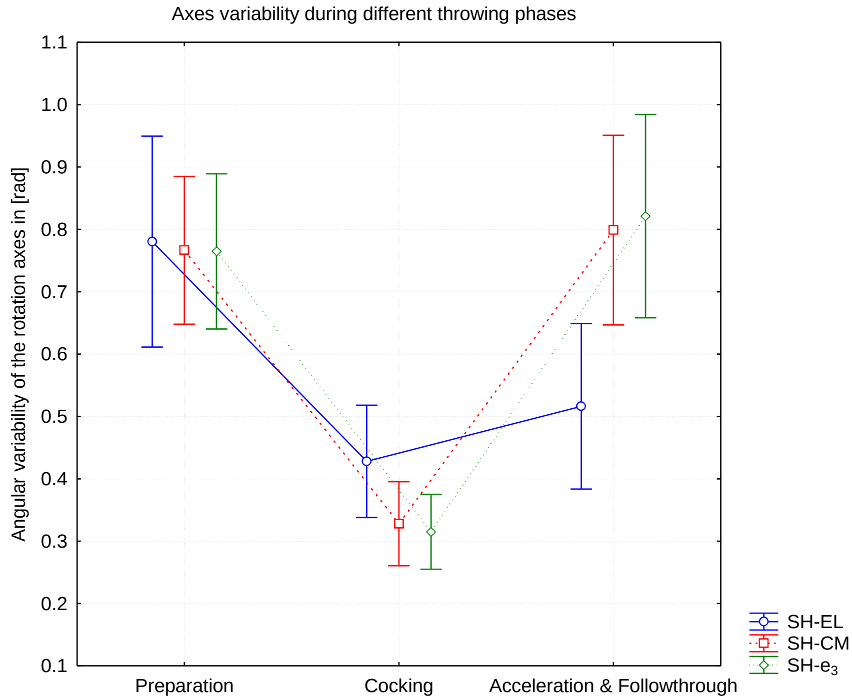

Figure 1. Angular variability of the rotation axes (SH-EL, SH-CM, SH-e_3) of each throwing phase

The present experiment was designed to test the hypothesis that a change of rotation axis occurs during overarm throwing. During the cocking phase which is related to an arm rotations with high velocity profiles would cause the limb to rotate around an axis closely aligned to e3. Our findings confirm that the CNS uses different control strategies during multi-joint movements and may even change them during the movement itself. This study was conducted in collaboration with Prof. Venture from the Tokyo University of Agriculture and Technology and was supported by the Japan Society for the Promotion of Science (JSPS/FF1/391 ID No. PE 12509).

Poster #125

Lack of effects of aging on using mechanical advantage in multi-finger prehension

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ABSTRACT

Research shows that during grasping, humans prefer to exert torque on the object by increasing forces produced by fingers with larger moment arms. Such preference, addressed as using mechanical advantage, has been seen in young subjects, where increasing a specific finger's moment arm resulted in larger force and torque production of that finger. Healthy ageing is associated with gradual deterioration in morphology and physiology of the neuromuscular system that leads to impaired control and modulation of the motor output. We hypothesized that older adults would differ from their younger counterparts in their ability to use mechanical advantage in grasping tasks under manipulation of moment arms of the index finger normal and tangential forces. Eight young and eight elderly adults held vertically a handle instrumented with five force sensors. Additional weight was fixed below the handle at two different positions to generate pronation and supination torque conditions. Subjects were asked to resist the external torques and maintain handle orientation. To increase moment arm of index normal force the index force sensor was moved vertically away from the middle finger, and to increase moment arm of index tangential force, an additional spacer was put on top of the index sensor. Overall, elderly subjects produced larger finger torques and forces compared to young subjects. This was associated with larger internal forces and moments produced in the direction of the external torque in older adults. Contrary to previous studies, both age groups showed no effect of increased tangential and normal moment arms on the corresponding index finger forces. For both groups, torques produced by both forces increased, but only torques due to tangential forces of the index finger changed significantly. We conclude that even though ageing changes torque and force production during grasping, there was no age effect on utilizing mechanical advantage of the index finger.

Poster #150

Gait initiation to a moving surface: modulation of anticipatory postural adjustment.

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ABSTRACT

Usually, gait initiation is preceded by anticipatory postural adjustment (APA), characterized by a shift of the center of pressure (CoP) initially backward and laterally toward the leading leg and then toward the supporting leg, thus preparing the body forward propulsion. When stepping on a moving surface (e.g. of a sidewalk or an escalator), postural stability may be affected depending on the velocity of a moving surface and by the perturbation induced when the leading leg lands on that surface. In anticipation of these effects, the APA may be modified when gait is initiated to a moving surface. To verify this assumption, we asked subjects standing on a motionless force platform, to initiate gait by stepping on a treadmill surface moving at four different velocities 0.0, 0.25, 0.5, and 0.75 m/s. Whole body (center of mass) kinematics and CoP displacements were recorded. APA was identified as a change in the baseline activity of ground reaction forces and CoP before the first movement of the heel of the leading leg. Preliminary results showed that the duration of APA and the length of the first step did not change across velocities. However, the velocity of the centre of mass, the initial lateral excursion of the CoP, the area covered by the CoP, and the cumulated distance of CoP over APA period were higher in the faster (0.5 and 0.75 m/s) compared to lower velocity conditions. The increase of APA magnitude led to an increase in the mean velocity of the center of mass during and after APA period to cope with the increasing task demand, despite the absence of changes in the duration of APA and the length of the first step. Results show the existence of different control strategies to deal with time constraints and anticipated perturbations. Additionally, the study identifies the range of APA adjustments preceding gait initiation to a moving surface in healthy subjects, which provides a basis for identifying the problems of gait initiation and stability in subjects with neurological movement deficits.

Poster #151

Influence of intra-auditory sensory integration in isometric finger force production

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ABSTRACT

Sensory information plays a critical role in learning motor skills, adapting to new environments, and maintaining accurate performance of motor activities. The enhancement of motor performance is based in part on the ability to utilize sensory information. Most of sensorimotor studies have been done primarily with respect to the visual modality. The effects of auditory sensory on a fine motor performance are not clearly understood. The purpose of this study was to investigate integration of intra-auditory sensory modalities in sub-maximal isometric finger force production. Fifteen right-handed male adults participated as subjects for this study. A target tone (1000Hz & 50dB) presented to participant's the left ear and a tracking tone presented to their right ear via a headphone. The tracking tone was proportional to total finger force and determined by three conditions: frequency change condition (F), amplitude of sound change condition (M), both frequency and amplitude change condition (F+M) at each low and high feedback resolution. Participants were asked to match the tracking tone with the target tone. Performance error (PE-distance between force output and target), correction error (CE-distance between force output and its mean), estimation error (EE-distance between mean force output and target) were calculated for each subject. PE can be expressed by summation of CE and EE. The results showed that participants had lower PE and CE for F+M at low resolution than for either F or M. This indicates that participants were able to integrate two distinct auditory modalities to produce and maintain the required force level with less variation when auditory feedbacks were weak. This supports the inverse effectiveness rule. That is, multisensory enhancement increases as stimulus saliency decreases. All three errors (PE, CE, and EE) were lower at high resolution than at low resolution. It may suggest that participants were less accurate to produce and maintain the required target force when lower amount of auditory feedback information was presented. This result is consistent with previous findings in visuomotor studies. We conclude that intra-auditory integration on finger force output follows the inverse effectiveness rule and the amount of auditory feedback information is associated with the finger force variability.

Poster #155

Postural asymmetry and muscular demands in young and elderly adults during quiet and relaxed standing

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ABSTRACT

During daily life activities people stand in an unconstrained manner. They periodically produce postural changes by transferring body weight (BW) from one leg to the other and adopt asymmetric postures. However, it has been shown that elderly individuals produce less postural changes and move less than young adults; what could suggest a cocontraction pattern of muscle activation by the elderly individuals. If such behavior is associated with higher muscular activity, it could induce fatigue which may increase the risk of falling. The aim of the study was to compare BW asymmetry and muscle activity in young and elderly adults during quiet and relaxed standing. Nine young (26±4 years; Y group) and six elderly subjects (77±2 years; E group) performed two standing tasks: relaxed standing watching a television documentary (for 15 minutes and they were allowed to change their posture freely at any time) and quiet standing (for 70 seconds). They stood with each leg placed on different force plates and we also registered the electrical activity of selected lower-limb muscles. Using the vertical component of the ground reaction force measured by each force plate, we calculated an asymmetry index (the difference between the BW of the right and left legs normalized by the total BW) and examined the relation between muscle activity and the BW asymmetry across time for each standing task. For quiet standing we found small values of asymmetry; 4±2% for the Y group and 8±4% for the E group. On relaxed standing, the Y group presented 25±17% of BW asymmetry; 76% of the time they stood in a small BW asymmetry range (between 1-10%) and 17% of the time in a large asymmetry range (75-90%). The E group presented 7±4% of BW asymmetry during relaxed standing, (100% of the time they stood in an asymmetry range between 1-30%). Conversely to the Y group, the E group produced higher activity of the thigh muscles (20-30% of MCVI) during quiet and relaxed standing. We concluded that during relaxed standing, the elderly individuals adopted a different pattern of transferring BW and presented higher muscle activity which may induce fatigue and compromise the efficiency of postural control.

Poster #170

The effects of soldier load on action perception and posture dependent target engagement timing

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ABSTRACT

Task oriented actions of the upper body are constrained by trunk orientation. Protective gear and equipment on the head and trunk will impact the soldier's ability to pick up information from the environment, especially when transitioning from one task to another. The purpose of the current experiment was to examine the effect of load on body orientation and perception of environmental information during target engagement following a landing task. Five Special Forces soldiers (Height: 1.84 ± .09 meters, weight: 96.8 ± 16.2 kg) were recruited. Participants were instructed to jump from a 14 inch platform onto two adjacent force platforms 30 times for each of 7 load configurations (Figure). Upon landing a 20/20 visual acuity "C" optotype was presented on a monitor 5 meters to their front at eye level. The opening of the "C" indicated which of two targets to shoot first, firing twice and as fast and accurately as possible (TP1&TP2). Once the 1st target was engaged the subject was to immediately transition to the 2nd target and repeat the double firing sequence (TP3&TP4). Targets were located at shoulder level and spaced 10 meters apart. Segmental kinematic and kinetic data were collected using an 8 camera Qualisys motion capture system synchronized with 2 AMTI force platforms. The following variables were calculated: (1) minimum sagittal plane head angles during landing (Head-Y), (2) the time to discriminate (TtD) was calculated from landing to "C" direction identification, and (3) the M/L center of pressure (COP) at the feet between TP2 & TP3 (COP-Y). ANOVA's were used to compare conditions of our initial subject and differences ($p<.05$) were found between loads in all three variables. Post hoc mean comparisons ($\alpha=.05$) indicated: (1) Negative Head-Y angles were greater than baseline for each condition except load condition 3(C3) which showed the least forward pitch, (2) Heavy helmet conditions did not have a delayed TtD relative to baseline but both light and heavy fire conditions did, (3) total COP-Y increased from light fire to heavy fire conditions (Figure). Increased downward pitch in all conditions except C3 indicates that load weight impacts the kinematic posture of the head. However, the load distribution of C3 could be attenuating the amount of absolute head flexion by pulling the trunk back more than the head is pitched forward. Greater negative Head-Y angles were related to increase TtD in all but the heavy head conditions. This suggests that load effects perception through reduction of the visual field. Additionally, a heavier head appears to stiffen the neck as an adaptive strategy against this loss. The COP-Y increase with heavier loads indicates an effect of the inertial characteristics of increased load on postural responses. These preliminary results indicate the effect of equipment load on the soldier's ability to discriminate visual cues and engage targets.

Poster #185

Arm movements against an elastic load with an unexpected change in stiffness

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ABSTRACT

Understanding how the nervous system controls movements in the presence of changing external loads is important for rehabilitation. There continues to be debates as to whether fast arm movements against a load are planned by the nervous system in terms of force, position, or equilibrium point. Our objective was to distinguish between these three hypotheses, by introducing an unexpected change in load stiffness during arm reaching movements. Seventeen healthy adults (mean age: 32 years) participated in the experiment. They were seated with their forearm in a splint, which was attached to a robotic device. Starting with their hand in front of their body, they had to perform fast reaching movements by pushing forward against the robot, programmed to produce an elastic load (k = 60 N/m), in one of three conditions. In the 'visual feedback' condition, a vertical bar was displayed on a computer monitor after each trial, whose length corresponded to the final force attained in that trial. Participants practiced that condition until they could attain the target final force of 10 N (corresponding to a reach distance of 16.7 cm) with an error of less than 10%, with peak velocity of at least 0.5 m/s and for at least 6 consecutive trials. Then, once every 3 trials, the vertical bar was not displayed ('no feedback' condition). Finally, in a random 33% of the no feedback trials, the stiffness of the elastic load was unexpectedly doubled to 120 N/m ('catch trials'). From the robot data, we computed final force, final position and peak velocity attained by participants in each trial. We also computed the work done by participants against the robot, as the integral of the initial force impulse. These values were compared across conditions using repeated measures ANOVA. We found no differences in any of the variables between the feedback and no feedback conditions, indicating that participants performed their reaching movements the same way in these two conditions. However, in the catch trials, participants produced a significantly shorter movement, with a significantly higher final force, than in either the visual feedback or the no feedback conditions. Initial work was not statistically different. Our results demonstrate that during the catch trials, where stiffness of the load was increased, participants neither maintained the same level of force (force control hypothesis) nor the same final position (position control hypothesis) as in the trials with regular stiffness, with or without visual force feedback. Our results are however consistent with the equilibrium point hypothesis, where the unexpected change in load stiffness causes the arm movement to end at a different point on the force/position characteristic of the arm.

Poster #195

Increased gravitational force reveals the mechanical nature of physiological tremor

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ABSTRACT

In the present experiments we used a large horizontal human centrifuge. By enclosing subjects in the centrifuge and spinning them for some time, we were able to record naturally occurring postural hand tremor over a range of 1 to 3 g. In this situation the rotating subject had to contend only with an increase in vertical force. In a second part of the experiment, masses were added to the hand of the stationary subject to generate force loadings comparable with those previously produced by the increased gravitational force. In the second part, the subject had to contend with increased vertical force and also the increased inertial load. It was thus possible to compare directly the effect of force loading and inertial loading of the limb on human physiological tremor. If, as we believe, tremor is largely a consequence of the spring / mass characteristics of the limb then its frequency should be systematically reduced by adding inertia. The amount of EMG required should not be altered. Unfortunately, the additional weight of the inertial load demands additional muscular effort and this will increase the EMG. It is thus normally impossible to distinguish the changes produced by increased inertia from those produced by increased effort. The advantage of using the centrifuge is that it allows us to disambiguate these changes. We recorded forearm EMG and limb acceleration peak frequencies in each condition. At its simplest, the increase in force produced in the centrifuge should not be associated with a change in frequency of tremor whereas corresponding inertial loading should (Fig1). There is, however, an additional complication that changes in muscular effort may also change limb stiffness slightly. We used the EMG and peak frequencies as inputs to a simple previously described model. We show that a very satisfactory explanation for hand tremor is that it results from a noisy EMG input into an underdamped second order oscillator. The result is important because it shows that it is not necessary to invoke "tremor generators" of spinal or central origin to explain physiological tremor. Belief in such neural oscillators is now widespread and may be misplaced.

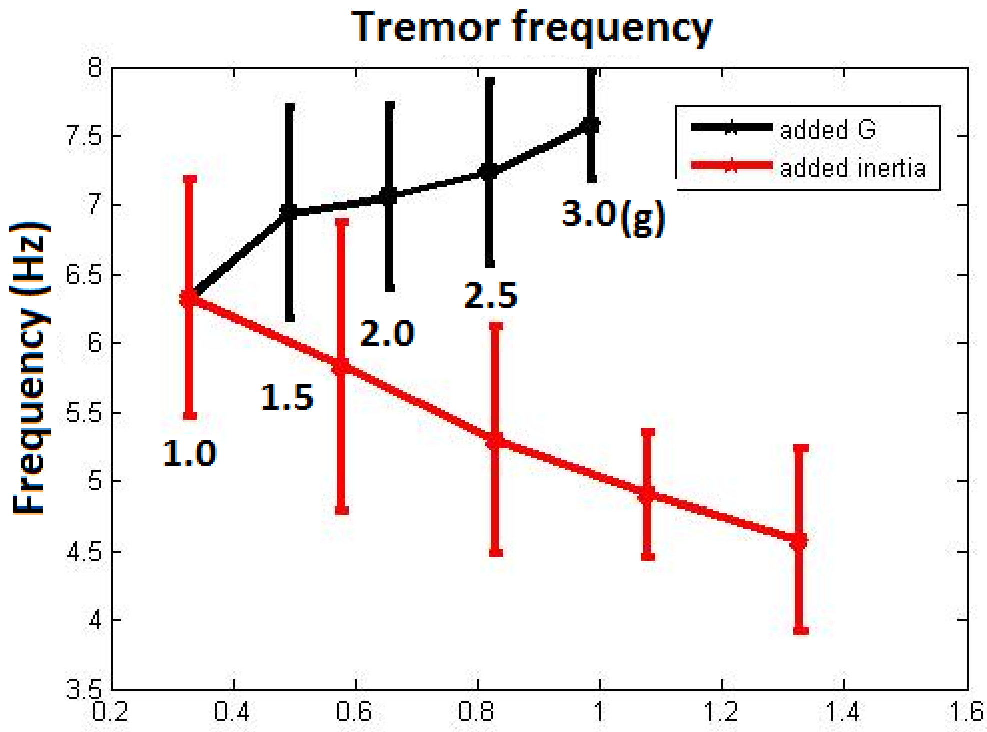

Figure 1. Corrected hand weight (kg)

Poster #198

Mechanisms of interpersonal sway synchrony

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ABSTRACT

Vision and touch of earth-fixed objects both contribute to postural control during stance. Recently it has also been shown that fingertip contact with another person reduces sway (Johannsen et al. 2012). This represents a complex control loop, with both persons relying on a moving reference point. Here we attempt to understand this control loop with a combination of experiment and modelling. We also determine whether vision of another person drives sway, and if this interacts with touch. We studied 8 pairs of subjects standing next to each other on separate forceplates. We included 3 conditions of touch (no contact, light touch, shoulder contact) and 3 visual conditions (both eyes closed, both open, asymmetric). Centre of pressure velocity (COP) was the primary measure of sway. The magnitude and timing of sway coupling was quantified by the COP-COP cross-correlation function (XCORR). Data were compared to a Simulink model (Peterka 2000) consisting of two PID-controlled inverted pendulums coupled together. All forms of physical contact (LT & SC) reduced sway, with a greater effect for shoulder contact ($p<0.01$). Vision also reduced sway, but had less effect with increasing tactile contact ($p<0.01$). When *only* light touch was available, XCORR's exhibited twin peaks at ~ -500 and +500ms lag. Vision alone produced almost identical results. However, vision and touch did not summate when both were available, suggesting sensory redundancy. During asymmetric vision, XCORR's showed a single peak at +500ms lag. In contrast to light touch, shoulder contact produced a single XCORR peak at ~ 0ms lag, irrespective of visual condition. We modelled the interaction in Simulink as follows. Firstly, to simulate effects of light touch & vision, we coupled both sensory feedback loops to each other, such that each (model) person's feedback error was summed with 20% of their partner's. This precisely recreated the XCORR twin peaks at +/- 500ms. Secondly, to model shoulder contact, we coupled the ankle torque output of each person via a stiff heavily-damped spring. This recreated the zero-latency XCORR peak. Firstly these results suggest that, when touching and/or observing another standing person, we assume the other person is a stable reference point; any force/position fluctuations are interpreted as self-motion. Secondly, tactile and visual sway coupling occurs via a bidirectional sensorimotor process with a delay in each direction of ~500ms. A 'switching' mechanism, whereby a sway leader and follower periodically swap roles, is not necessary to explain this interaction; a *continuous* control model was sufficient to recreate the XCORR's. Lastly, shoulder contact was successfully modelled by a simple direct mechanical linkage, explaining the zero-latency response. These results provide a novel framework for estimating sensory and mechanical postural interactions during stance.

Poster #199

Age-related changes in the vestibular control of balance

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ABSTRACT

Falls are a major problem for older people but the underlying mechanisms are not well understood. The vestibular system is evidently important for the control of upright posture, as a counteractive postural adjustment is normally evoked when this system senses a balance disturbance. Since ageing is associated with degeneration of the peripheral and central vestibular system, the higher incidence of falls in older people may be partially attributable to a vestibular mechanism. Here we examined balance reflexes evoked by stochastic vestibular stimulation (SVS) in three groups of human subjects; young (n=15, 28±7years), middle-aged (n=12, 55±6years) and older adults (n=17, 77±5years) (mean±SD). A randomly varying electrical current (filtered white noise, 0-20Hz; RMS amplitude, 0.6mA) was passed between the mastoids of subjects stood with feet together, eyes closed and head facing directly forward. As stimulation of this type evokes a balance response directed along the interaural line, medio-lateral ground reaction shear force (Fx) was measured for the duration of each trial (6 x 30sec). The cumulant density function was then used to estimate the time-domain relationship between the stimulating waveform and the evoked response. The resulting SVS-Fx relationship comprised an initial negative peak after 128±14ms followed by a larger positive peak after 305±48ms. These two components are termed the short latency (SL) and medium latency (ML) responses, respectively. While age group had no effect on the response latency ($F_{2,41}=0.88$, $p=0.43$), the magnitude of the two components was differently affected by ageing ($F_{2,41}=12.77$, $p<0.001$). The SL response tended to decrease in older adults. Average SL magnitude reduced by 34% between young and older adults, though this difference was not quite significant (pairwise comparison, p=0.06). In contrast, the ML response was substantially and significantly increased in the middle-aged and older groups (pairwise comparisons, both p<0.02). The size of this component was increased by ~40% in both groups compared to young adults. Although the origin of the SL motor response is open to debate, the ML response has been attributed to a virtual semicircular canal signal of head roll, and its direction is congruent with the resulting body sway. Our results demonstrate that this functional balance response evoked by electrical activation of semicircular canal afferents is increased in older people. Since the site of electrical activation bypasses the end organ mechanics, this finding may reflect an increased afferent or central sensitivity in order to compensate for an age-related loss of peripheral vestibular hair cells.

POSTER SESSION II (continued):

Theme IV: Motor Control of Speech and Language

Proc. IXth International Conference on Progress in Motor Control (PMCIX)

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Poster #26

Neural correlates of speech recovery after intra-oral surgery

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ABSTRACT

Intra-oral surgery in orofacial peripheral motor apparatus usually induces dramatic changes in speech motor control and often requires the patient to go through a long speech recovery process. This study aims at better understanding the reorganization process at the cortical and subcortical levels underlying the functional recovery of speech after mouth surgery (i.e. carcinologic resection of mobile tongue and/or mouth floor). In order to determine how the brain integrates new relationships between motor commands, auditory and orosensory feedbacks and new inter-articulators coordination, we designed a longitudinal sparse-sampling fMRI study based on orofacial, vocalic and syllabic production tasks on 10 patients one week before, one month and three months after surgery. Before surgery, less neural activity was observed in sensorimotor regions in patients compared to healthy subjects while, one month after intra-oral resection, an increase of activity was observed in the supplementary motor area and in the cingulate cortex (both involved in selection and initiation process suggesting more competitive mechanisms between motor strategies after surgery). Additional patients are still currently recruited and we expect the speech recovery process to be also associated with significant activity changes in the cerebellum in relation with changes in motor plant. A longitudinal VBM (Voxel Based Morphometry) analysis will also be performed in order to study potential differences of grey and white matter between the two groups and before/after orosurgery. These results will contribute to better understand the neural reorganization of sensory-motor structures associated with the speech production recovery process and brain mechanisms involved in relearning speech with a focus on internal model development and perceptuo-motor coupling.

Poster #32

Sensory-motor adaptive changes of orofacial and speech actions without overt motor behavior: an fMRI-adaptation

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ABSTRACT

The concept of internal forward models that internally simulate the sensory consequences of an action is a central idea in speech motor control. While recent studies have provided evidence for on-line auditory and somatosensory feedback control mechanisms during overt speech production, the existence of motor-to-sensory control loops during imagined orofacial and speech actions remains however unclear. In the present study, we used a repetition suppression paradigm while measuring neural activity with fMRI during overt and covert repeated orofacial and speech actions. In the motor domain, this paradigm refers to decreased activity in specific neural populations due to repeated motor acts and has been proposed to reflect sensory-motor adaptation. Sensory-motor adaptive changes during both overt and covert repeated orofacial and speech actions would support the hypothesis that motor simulation relies, at least partly, on motor-to-sensory control mechanisms common with those for motor execution. Methods: Orofacial movements and syllables were overtly or covertly produced by 12 healthy adults while lying in a 3T MRI scanner, with a sparse-sampling acquisition method used to minimize movement-related image artifacts. Results & Discussion: Overall, overt orofacial and speech actions activated a set of largely overlapping brain areas, including the sensory-motor and premotor cortices, the sma and the cingulate cortex, the inferior parietal lobule, the auditory cortex, the insular cortex, the basal ganglia and the cerebellum. Common activity during overt and covert production tasks was specifically observed in the sma and the premotor cortices. Crucially, suppressed neural responses during overt and covert repeated orofacial and speech actions were observed in the left ventral premotor cortex, the sma and the superior parietal lobule. These results suggest sensory-motor adaptive control of imagined orofacial and speech actions in these motor and parietal regions.

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Poster #37

Speech motor control in aging: effects of sequencing and articulatory complexity

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ABSTRACT

The manner and extent to which age affects the cortical speech production system is undetermined. In a previous study, we showed lower activation in older compared to younger adults during speech production in multiple areas including the SMA-proper and the ventral premotor cortex (PMv) during a simple word repetition task, in the absence of age-related behavioural differences. The goal of the present study was to further examine the relationship between speech production and age-related structural and functional neural changes. 15 young (26.8±4.8 y) and 15 healthy older adults (68±3.9 y) repeated visually presented sequences of 6 syllables while lying in a 3T MRI scanner. A sparse sampling protocol was used. The syllables were either simple (one consonant + one vowel) or complex (one consonant cluster + one vowel). The sequences were either simple (1 syllable repeated 6 times) or complex (3 syllables repeated twice). Data were analyzed using a 2x2x2 ANCOVA with group, syllable complexity, and sequence complexity as factors, and several covariates (sex, hearing sensitivity). We found a significant Age x Sequence complexity interaction on the duration of the sequences, with complex sequences being produced more slowly by older adults. For RTs, we found a significant Age x Syllable Complexity x Sequence Complexity interaction. These results demonstrate that with age the planning and execution of complex speech acts becomes more effortful but that less complex acts are unaffected. At the neural level, speech production was associated with a broad age-independent bilateral network. Age-differences in sequence complexity were found in the left PMv, left PT, left M1, etc (Fig.1). Age-differences in syllable complexity were found in the bilateral supratemporal cortex, SMA, etc. Ongoing analyses will reveal whether behavioural performance is explained by age-related changes in BOLD signal and normal age-related brain atrophy.

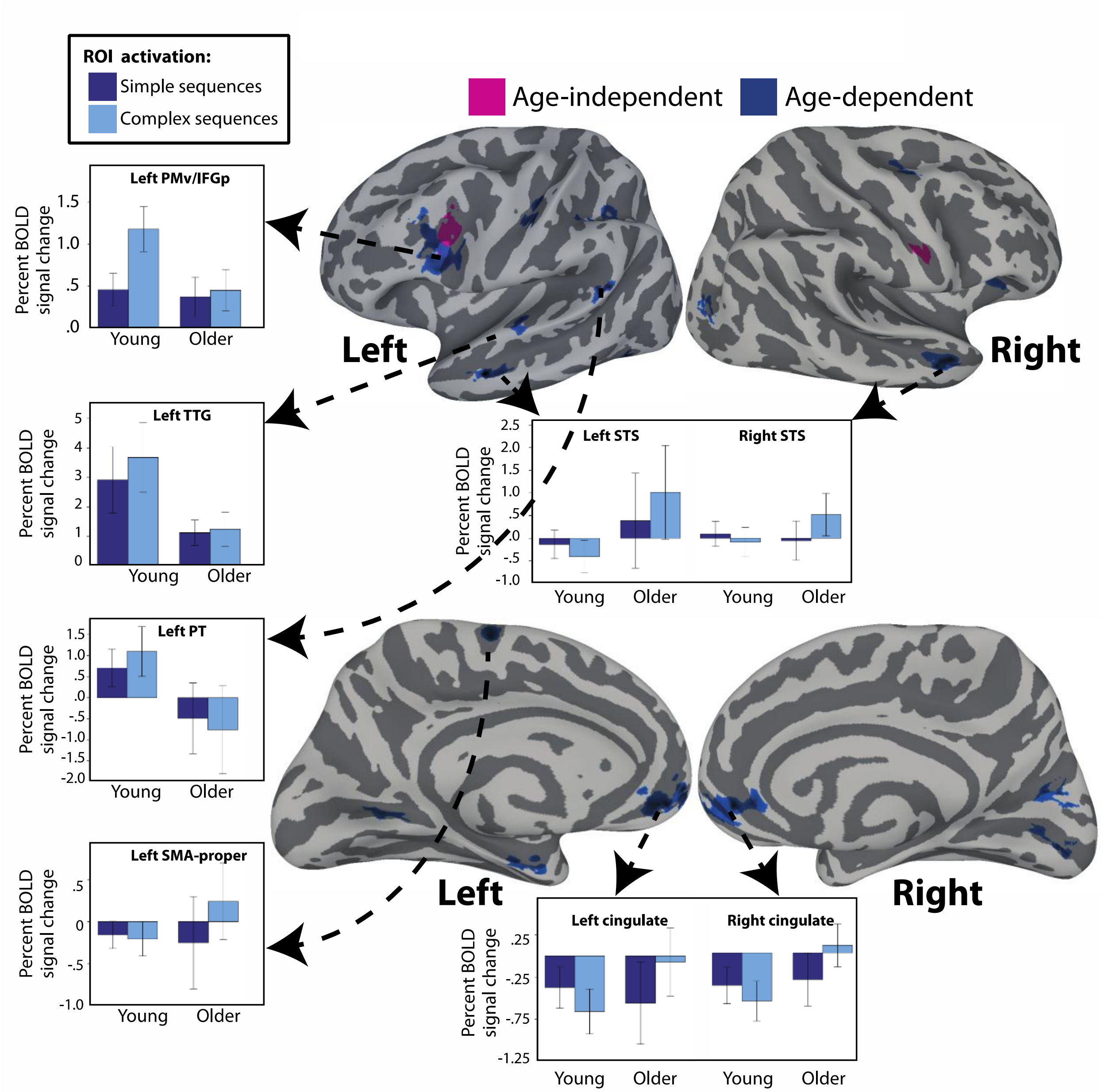

Figure 1. Sequence Complexity Effects.

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Poster #63

Experience-dependent modulation of feedback integration during singing: role of the right anterior insula

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ABSTRACT

Somatosensation plays an important role in the motor control of vocal functions, yet its neural correlate and relation to vocal learning are not well understood. We used fMRI in 17 trained singers and 12 nonsingers to study the effects of vocal-fold anesthesia on the vocal-motor singing network as a function of singing expertise. Tasks required participants to sing musical target intervals under normal conditions and after anesthesia. At the behavioral level, anesthesia altered pitch accuracy in both groups, but singers were less affected than nonsingers, indicating an experience-dependent effect of the intervention. At the neural level, this difference was accompanied by distinct patterns of decreased activation in singers (cortical and subcortical sensory and motor areas) and nonsingers (subcortical motor areas only) respectively, suggesting that anesthesia affected the higher-level voluntary (explicit) motor and sensorimotor integration network more in experienced singers, and the lower-level (implicit) subcortical motor loops in nonsingers. The right anterior insular cortex (AIC) was identified as the principal area dissociating the effect of expertise as a function of anesthesia by three separate sources of evidence. First, it responded differently to anesthesia in singers (decreased activation) and nonsingers (increased activation). Second, functional connectivity between AIC and bilateral A1, M1, and S1 was reduced in singers but augmented in nonsingers. Third, increased BOLD activity in right AIC in singers was correlated with larger pitch deviation under anesthesia. We conclude that the right AIC and sensory-motor areas play a role in experience-dependent modulation of feedback integration for vocal motor control during singing.

Poster #100

Hearing action verbs affects postural control

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ABSTRACT

It has been shown that simply hearing words that convey an action (e.g. "grasping") activate brain areas related to the execution of that action (e.g., Desai et al., 2010). More recently, a number of studies have demonstrated that motor behaviours may also be modulated following the auditory presentation of action verbs. In particular, two recent studies (Frak et al., 2010; Aravena et al., 2012) have demonstrated a systematic increase in grip force when participants hear action verbs related to manual actions. The goal of the present study was to determine whether such a perception-action link could be demonstrated in the control of a very different motor behaviour: the control of standing posture. In the present study, quiet standing was evaluated in 16 young adults (22-32 years) during the auditory presentation of a sequence of verbs, only half of which were actions verbs related to lower limb movement. The two sets of words were acoustically matched in amplitude and duration. Centre of foot pressure (COP) displacements were recorded using a force platform. A number of postural sway parameters were examined, including range and mean velocity of COP displacement along the anterior–posterior (A/P) and medial–lateral (M/L) axes. Results showed larger and faster displacements of COP along the A/P axis when actions verbs were heard, compared with non-action verbs ($p<0.05$). No such effect was observed for the M/L axis. To our knowledge, this is the first evidence of a relation between language and motor processing related to postural motor control.

Poster #143

Sonifying handwriting movements as real-time auditory feedback for the rehabilitation of dysgraphia

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ABSTRACT

Although almost all motor activities are silent, the modality of sound can be used to inform about the correctness of the ongoing movement, without interfering with the visual and proprioceptive feedback. Furthermore, the dynamic features of sounds make them particularly relevant for informing about the spatiotemporal characteristics of movements. Finally, because of their (potentially) playful character, sounds are potentially efficient for motivating patients, children for instance, in particular need of such assistance. From these theoretical considerations, we proposed to sonify handwriting movements in order to facilitate the rehabilitation of dysgraphia. Dysgraphia refers to mechanical difficulties in handwriting production related to a lack of motor control in children having neither neurological nor other motor deficits. Nowadays, handwriting movements can be recorded with graphic tablets at high temporal and spatial resolution. Two challenges appeared: first, finding the relevant variables associated with the different sounds; second, finding the appropriate auditory dimension(s) on which to map the handwriting movements. We hypothesized that sound is well suited to inform about hidden variables of handwriting movement (which cannot be supplied by vision) and we decided to sonify two kinematic variables: the instantaneous tangential velocity and the unexpected velocity peaks. Unexpected velocity peaks have been shown to be directly related to non-fluent handwriting movements. Finally, the pressure applied by the pen on the graphic tablet was associated with the global volume of the sound. We are currently testing these movement/sound associations in seven dysgraphic children in a longitudinal protocol of handwriting rehabilitation. The experiment is divided into six 20-minutes weekly sessions. Each session is organized in identical manner, including a pre-test without sound, a practice with auditory feedback and a post-test without sound. In the pre- and post-tests, tasks are strictly identical and thus can be used to follow the rehabilitation evolution, within and between sessions. Preliminary data from the three first sessions revealed a positive effect of the sonification procedure: Dysgraphic children appeared to be able to write faster and with more fluent movements. These first promising results will be soon completed with an additional control group in which other dysgraphic children will run the same protocol without auditory feedback, in order to confirm the positive effect of adding sounds. We propose that sounds may be used as a palliative way to inform about kinematics of handwriting movements and, maybe, to assist movement rehabilitation in general.

Poster #158

Bimodal sensory influence in speech control

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ABSTRACT

Recent studies have shown that speech can be guided in real-time by sensory information (e.g. auditory, tactile, proprioceptive), contrary to traditional views that posited that feedback loops are too slow for rapid motor adjustments. Although the importance of sensory information for rapid adjustments and stabilization of ongoing speech movements has been established, there is a limited literature on how the central nervous system weights sensory feedback from multiple sources during speech production. The present study investigated auditory-proprioceptive (bimodal) integration in speech using a formant shifting paradigm with masseter tendon vibration. Five young adult male speakers repetitively produced the word "dead" with their first formant gradually shifted down (i.e. the auditory feedback moved closer to "did") to a maximum shift of 250 Hz, either with or without masseter tendon vibration. Acoustically, real-time formant perturbation often results in a compensatory shift in the opposite direction (i.e. towards a low vowel – "dad"). On the other hand, altering the activity of the masseter muscle spindles via tendon vibration is known to produce jaw movement undershoot and increase variability in articulatory coordination (between jaw-lip-tongue). It was hypothesized that, if jaw proprioceptive information is integrated with acoustic information in real-time, then the response to perturbation (formant shifts) would be differentially altered depending on the relative importance of these two sources for guiding speech movements. A wide variety of systematic responses were observed, including no acoustical response in all conditions, the same degree of acoustical compensation in both conditions, and either increased or decreased compensation during tendon vibration. In general the results indicate substantial and systematic individual differences in the integration of jaw proprioceptive information for the control of speech. This suggests that the relative contribution of feedback and feedforward systems may vary considerably across speakers, as well as the relative weight of different feedback modalities. These results are compatible with the notion of integrated multi-sensory maps underlying speech production, but suggest substantial cross-speaker differences in the weighting, and possibly representation of these maps.

POSTER SESSION III:

Theme V: Motor Control and Recovery from Injury

Poster #21

Preferred joint control pattern during 3D arm movements with abundant degrees of freedom

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ABSTRACT

How abundant degrees of freedom (DOFs) are utilized during natural arm movements remains under debate. The leading joint hypothesis predicts a preference to perform movements by accelerating one (leading) joint actively and allowing the other (subordinate) joints to be moved largely by passive torques. Here, a hypothesis was tested that the abundance of DOFs is exploited to support the preferred control strategy during movements in different directions. A center-out free-stroke drawing task was performed that provided freedom in selection of direction of each stroke. The strokes were produced with the tip of the right index finger from the center to the perimeter of a horizontal circle. The instruction was to produce strokes as fast as possible and to select movement directions in a random order. The most frequently selected directions were identified as preferred. The task was performed in two conditions, with motion of the arm constrained to the horizontal plane (C) and with the wrist, elbow and shoulder motions being unconstrained (U). The joint control patterns in the preferred directions were compared between the two conditions with the use of muscle torque contribution (MTC, $0.0 \leq MTC \leq 1.0$) that assessed the portion of net torque generated by muscle torque at each joint. The preferred joint control strategy is characterized by $MTC > 0.5$ at the leading joint and $MTC < 0.5$ at the subordinate joints. In both conditions, consistent directional preferences were revealed. They were associated with maximal difference between shoulder and elbow MTC. However, the strength of the directional preferences was lower and the range of preferred directions was wider in the U compared with C condition. The wrist was not included in the analysis because its motion was negligible. The results supported the hypothesis that the abundance of arm's DOFs in the U condition was used to increase the range of directions in which active motion production is limited to a single joint.

Poster #30

A proof of concept approach towards a constrained-led bimanual rehabilitation strategy of inter-limb interactions following stroke

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ABSTRACT

Bimanual Movement Training (BMT) in stroke has led to increasing interests. Its utility remains however, controversial and poorly understood (Cauraugh et al. 2010). Actually, the literature lacks a BMT strategy dedicated to the re-adaptation of bimanual synergies, rather than toward only facilitating the paretic limb control (Sleimen-Malkoun et al. 2010, 2011). On the basis of the theory of Coordination Dynamics in brain and behavior (Kelso 1995), we proposed a conceptually founded approach to constraint-led bimanual rehabilitation strategy based on manipulation of the balance between coupling and symmetry breaking in a discrete bimanual aiming task. To test our predictions, we adopted a proof of concept approach consisting in a qualitative analysis of the signatures of task- and stroke-induced asymmetries in patients with different degrees of impairments, by analyzing the intra-individual inter-trial variability. Patients underwent a 6 week BMT program aiming at re-training them to overcome the desynchronized CVA-induced pattern, and to re-stabilize the initial synchronized pattern. Analysis of the inter-limb spatio-temporal relationship between hands revealed the presence of a competition between coupling and symmetry breaking phenomena, which resulted in the production of different bimanual patterns across trials (from desynchronized to fully synchronized). It also showed that task constraints favored, or conversely, hindered the expression of a coupling and hence, a synchronized behavior. Following the training program, patients presented changes in their behavioral repertoire: the number of desynchronized trials decreased and the occurrence of the healthy-like synchronized behavior increased. Our findings provided a proof of concept on how CVA- and task-induced inter-limb asymmetries should be taken into account in BMT and highlighted the importance of restoring bimanual synergies as part of a comprehensive rehabilitation protocol following stroke.

Poster #39

A novel treatment for Mal de Debarquement syndrome: A case study using transcranial direct current stimulation

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ABSTRACT

Persistent Mal de Debarquement syndrome (MdDS) is a rare disorder of continued perceived motion. Usually following habituation to passive background movement (such as being on a boat or yacht), MdDS occurs when the individual is unable to readapt to stable ground, giving rise to phantom perception of being unbalanced and continually moving. It has been proposed that MdDS may be a neurophysiological disorder with recent evidence using transcranial magnetic stimulation (TMS) demonstrating increased corticomotor excitability. Here, we report the outcome of 2 weeks of transcranial direct current stimulation (tDCS) treatment in a female with MdDS. The patient was an 80-year-old female (161 cm, 69.5 kg) who, following a boat cruise 10 years previously, complained of continual unsteadiness and difficulty in maintaining balance, particularly when walking up and down ramps. The Berg Balance Scale (BBS) showed a low-falls risk, with an initial score of 48 (56 max), however the Activities-specific Balance Confidence (ABC) Scale showed a low level of physical functioning (38.8%). As a result, the patient avoided stairs, ramps, or crowded venues. Single and paired-pulse (3 ms) TMS was given prior to and after the tDCS treatment. The patient underwent ten sessions of 20 min of cathodal tDCS at 1 mA intensity over a two-week period. There were no contraindications with tDCS treatment. Following treatment, little change was observed in the BBS (score 45/56), however the patient noted subjective improvements in sleep and balance which were supported by improvements in the ABC (70.3%). Corticomotor excitability had reduced by 32% whilst intracortical inhibition had increased by 5%. This case study provides preliminary evidence that low-level tDCS is a safe treatment for use with people suffering from MdDS. tDCS has an effect on the neurophysiology that may assist with activities requiring balance for this rare condition.

Poster #50

Does treadmill walking with metronome have any effect on lower limb loading within both stance and automatic postural reaction in stroke patients?

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ABSTRACT

Therapy based on treadmill walking with metronome is a popular method for gait re-education after stroke. The aim of this therapy is to optimize the time spatial characteristics of walking. Benefits of therapy are demonstrated by numbers of studies. The question is, whether the walk symmetrization during treadmill training with acoustic feedback has an immediate response on symmetrization of lower limb loading during standing and in automatic postural reactions. Patients were measured before and after walk therapy by NeuroCom's Smart Equitest System. 1) The Motor Control Test assesses the automatic postural reactions after an unexpected external disturbance (parameter: weight symmetry [%]); 2) Weight Bearing/Squat – assesses the stance symmetry (parameter: body weight [%]). The therapy on C-mill Force Link B.V. started after the initial examination. After three minutes of walking we turned on the metronome. The patient's aim was to keep walking rhythm with the symmetric rhythm of metronome. The therapy lasted 7 minutes. Then we repeated the tests by NeuroCom. Tests were performed on 11 patients (aged 49 ± 12; 9 men and 2 women) with right-sided hemiparesis in the chronic phase. All patients were able to stand steadily without support and walk on the treadmill with. The measurements showed that the loading on paretic lower limb was increased in 1.8 % then before therapy. Distribution of body weight during unexpected platform translation was improved on 6.4 % after therapy. Conclusion: Our present results show a tendency to symmetrization of lower limb loading in steady position and also in automatic postural reactions after walking therapy on treadmill in post stroke patients. Based on these partial results, we assume that the treadmill therapy with acoustic feedback may lead to better symmetrization lower limb loading during standing and in automatic postural reactions. This research was supported by CZ.1.07/2.3.00/20.0163.

Poster #59

Central contribution to "extra torque" during neuromuscular electrical stimulation

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ABSTRACT

Neuromuscular electrical stimulation (NMES) generates contractions through peripheral and central mechanisms. The central contribution can be augmented by 100Hz bursts of NMES which can generate "extra" torque". Extra torque was abolished during a nerve block, providing strong evidence for a central origin (Bergquist et al. 2011). In contrast, Frigon et al. (2011) showed that the not abolished during a nerve block, providing strong evidence that it was not of central origin. We aimed to compare torque generated using Frigon's protocol (Frigon et al. 2011) and our own (Bergquist et al. 2011). NMES (1 ms pulses) was applied to generate plantarflexion torque, measured with the hip at ~90°. The protocol 1 (Frigon et al. 2011) consisted of the knee extended (170°-180°). The protocol 2 consisted of knee flexed (90°). For both protocols, we tested the ankle joint angle at 90° and 120°. The stimulating electrodes were placed over the gastrocnemius muscles (Frigon et al., 2011), over the gastrocnemius and soleus, and over the tibial nerve. For each protocol 3 trains of NMES (20–100–20 Hz for 3–2–3 s, respectively) were delivered 60 s apart. The stimulation intensity was set to evoked 10-15% of the maximal evoked twitch torque. Torque was averaged over two time intervals (Time1; 2–3 s into the train) and (Time2; 7–8 s into the train), and quantified as the percent increase from Time1 to Time2. EMG was recorded from the soleus muscle (M-waves and H-reflexes) and analyzed in the same time intervals as the torque (n=13). Extra toque was not different between protocols. Nerve stimulation generated larger H-reflexes while muscle belly stimulation generated larger M-waves. Even though extra torque was the same between protocols, seems that the mechanism of extra torque generation depends on the place of stimulation where nerve stimulation has a larger central contribution (larger H-reflexes) while muscle belly stimulation uses peripheral mechanisms (larger M-waves).

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Poster #61

Comparison of electromyographic abdominal muscle activity during abdominal muscle performance tests performed in two different planes

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ABSTRACT

Inadequate abdominal muscle performance is frequently identified as an impairment that may lead to functional limitation and disability in persons with low back pain. In order to accurately assess motor performance of these muscles, clinicians need objective measures that are both valid and reliable. Several tools exist to measure these muscles; however, which tests sufficiently challenge these muscles during clinical assessment is unknown. The purpose of this study was to compare abdominal muscle electromyography (EMG) activity during a muscle performance test performed in a sagittal plane (Lower Abdominal Muscle Progression (LAMP)) with one performed in a diagonal plane (Diagonal Muscle Progression (DMP)). Nine healthy participants (4 male, 5 female) were tested under two conditions: Lower Abdominal Muscle Performance (LAMP) and Diagonal Muscle Progression (DMP). Surface EMG activity of the upper (URA) and lower RA (LRA), IO, and EO muscles was collected. MATLAB was used to write custom codes to process the raw EMG and percent MVIC was compared to examine differences between the LAMP and DMP. The LAMP produced significantly greater activation of the abdominal muscles compared to the DMP, except for the IO. Additionally, an OI-URA Index indicated greater preference of the IO during the DMP. Movements of the lower limb in different planes pose different demands on the abdominal muscles. This study demonstrates that lower limb movement in a sagittal plane produces greater activity of the EO, URA, and LRA. However, diagonal plane movement produced greater activity of the IO muscle in relation to the URA. Further testing of these assessments is necessary to determine their responsiveness to change following training and in subjects with other characteristics, such as low back pain.

Poster #73

The relationship between cadence, step length, gait velocity, and impairment post-stroke

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ABSTRACT

Following stroke, gait velocity is slowed and often is lower than what is required for independent community ambulation. Since velocity is a product of changes in cadence and/or step length, the specific capacity to increase velocity depends on the ability to increase these two gait parameters. However, the strategy of using cadence or step length to increase gait speed may be influenced by stroke-specific impairments. Therefore an individual's capacity to increase gait speed may be uniquely influenced by the ability to increase either cadence or step length. The objective is to determine the relationship between cadence and step length to velocity by comparing across individuals who have had a stroke who walk at different speeds and who have different impairments. A retrospective analysis was conducted using data from the Heart and Stroke Foundation Centre for Stroke Recovery Rehabilitation Affiliates Database. A total of 77 participants were included in the analysis. Gait measures for preferred walking speed were collected using a GAITRite® Walkway. Clinical outcome measures (BBS, CMSA, MAS) and demographics were also compared across different self-selected speeds. Faster walkers at both preferred and fast velocity relied more on step length than cadence (cadence-to-step length ratio of 1.70 and 1.87 respectively) to increase velocity, compared to slower walkers (2.06 and 2.09 respectively) at both speeds. When groups were stratified by differing levels of impairment (BBS, CMSA, and MAS), cadence-to-step length ratio was shown to be significantly different ($p<0.05$) between impairment levels at both preferred and fast gait velocity. Individuals with a higher cadence-to-step length ratio achieve a lower gait velocity and have a higher level of impairment. Research focused on manipulating this ratio by selectively focusing on cadence and/or step length to increase gait velocity is warranted.

Poster #74

Comparison between different stages of Parkinson's disease on functional mobility, clinical and cognitive parameters

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ABSTRACT

Functional mobility, clinical and cognitive statuses are important to a functional and independent life style in Parkinson's disease patients. Also, exercise programs should focus in specific patient's needs to maintain/improve these aspects. In this way, it is fundamental to know the initial conditions of patients in different disease stages before commencing protocol training. The purpose of this study was to compare the initial conditions of mild and moderate patients with respect to their functional mobility, clinical and cognitive parameters. The study included 14 patients with PD assigned in two different groups according to their disease stages – defined by the Hoehn & Yahr Scale (H&Y): mild (8 individuals – 62.1 ± 10.8 years) and moderated (6 individuals – 74.6 ± 5.5). All assessments were carried out in the ''ON medication'' state, by applying the following tests: i) Clinical: scores on the motor section of the Unified Parkinson's Disease Rating Scale (UPDRS-III). ii). Functional mobility: Modified Timed Up and Go test (TUG); iii) Cognitive: Executive functions were assessed by the Wisconsin Card Sorting Test (WCST) with non-perseverative errors as an outcome measure. The concentrated attention was assessed by the Wechsler Adult Intelligence Scale – III (WAIS III), specify, symbol search (hit and error rate). The comparison between groups was conducted by the Mann Whitney non-parametric test for two independent samples The analysis showed differences on functional mobility - TUG ($U=3.00$; $p \leq 0.007$); UPDRS III ($U=8.00$; $p \leq 0.03$); WCST ($U=9.00$; $p \leq 0.05$) and WAIS III – hit rate ($U= 9.00$; $p \leq 0.05$) between groups. Conclusion: Functional mobility, clinical and cognitive statuses are more committed in higher PD stages. Therefore, disease stages should be considered on exercise programs design to fulfill specific needs of each one.

Poster #75

Reliability of a novel method to quantify postural control

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ABSTRACT

The process of maintaining an upright posture is a complex task that requires the human nervous system to integrate information from the somatosensory, visual, and vestibular systems. Postural control has been shown to vary across different groups and has been used to explain potential injury risk as well as recovery from injury for elderly individuals and young athletes. Postural control is often assessed by quantifying the magnitude of the center of pressure (COP) movement. However, these measures focus on the gross amount of movement and ignore the temporal structure of the COP signal. We have developed a novel non-linear analysis technique to characterize the temporal structure of the COP signal. The dependent variable determined using this technique is termed the entropic half-life (E1/2). The purpose of this study was to quantify the test-retest reliability of the E1/2 as well as four COP movement magnitude measurements (medio-lateral and anterior-posterior excursion, path length, 95% ellipse area). Twenty-seven healthy young adults completed single limb stance tasks increasing in sensory difficulty (rigid surface eyes open, rigid surface eyes closed, foam surface eyes open) on two separate occasions. Relative reliability was assessed using an intraclass correlation coefficient (ICC3,3). Absolute reliability was assessed using the standard error of the measurement (SEM) and the sensitivity of the measurement to true changes was assessed using the minimal detectable change (MDC95). The E1/2 was found to have high to very high reliability for all tasks tested (ICC range 0.82 – 0.91, SEM range 3.5 – 14.1 mm, MCD95 range 9.7 – 39.2 mm). The high reliability of the E1/2 is comparable to that of movement magnitude measurements. The E1/2 reflects how much of the previous postural position is used to determine the current postural control strategy (memory effect). This may be used in order to better understand the underlying motor control system.

Poster #77

Coordination of finger movements improves after piano training sessions in chronic stroke

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ABSTRACT

Little is known about the potential benefit of musical training on the ability of chronic stroke survivors to learn and reproduce coordinated finger movements. The purpose of this pilot study was to estimate the effects of a 3-week piano training program on piano performance measures, including speed of execution and note accuracy, in persons with chronic stroke. Four chronic stroke participants without musical experience participated in a 3-week piano training program that combined structured lessons (9 sessions of 60min) to home practice. Songs involving all 5 digits of the paretic hand were displayed by a MIDI program (Synthesia) and were played on an electronic keyboard. As the participant progressed, frequency (beat per minute [bpm]), complexity (finger sequences) and duration of songs increased. Within each song, the participants started at a tempo of 30bpm. When reaching a note accuracy and timing score of 80%, the tempo increased by steps of 10% up to 60bpm. Speed and accuracy were collected using Synthesia. Fine and gross manual dexterity was assessed pre and post-intervention using the Nine Hole Peg Test (NHPT) and Box and Block Test (BBT). Participants completed 3 to 4 songs during the training period, progressing through finger sequences of increasing complexity (consecutive fingers to intervals) and duration (from 17s to 38.5s). Each song was practiced on average 25 times before reaching a note accuracy >80% at a 60bpm. A mean reduction of 24.8s on the NHPT and mean increase of 6 blocks on the BBT was observed at post-intervention compared to pre-intervention scores. These preliminary results support the use of a piano training program to improve timing and accuracy of finger movements as well as manual dexterity of the paretic hand in chronic stroke survivors. The positive effects may be explained by the intensity and specificity of the intervention that also provided online multi-sensory feedback.

Poster #78

Robotic assessment of active motor control in stroke survivors with spasticity

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ABSTRACT

Spasticity is a common phenomenon post-stroke and is assessed by grading resistance to passive movement. However, little is known about the specific aspects of active motor control affected by spasticity. Recent evidence has shown that the KINARM™ robotic exoskeleton can be used to characterize upper limb function in stroke survivors. The current research aimed to determine whether this technology could characterize active control in a subgroup of the stroke population. Objective: Utilize the KINARM™ to identify motor control deficits during active tasks in stroke survivors with spasticity. Methods: 16 individuals (8 with elbow spasticity; Modified Ashworth Score > 1 [SPAS group] and 8 without elbow spasticity [STROKE group]) were recruited to participate. Active motor control was measured in the affected limb during the performance of three tasks in a projected digital environment: limb position matching, visually-guided reaching, and bilateral object hitting. Results: For the limb position matching task, the KINARM™ moved the affected arm to one of 4 positions, creating a square, to be matched with the unaffected arm. The ratio of the area moved by the unaffected arm compared to the KINARM™-controlled arm was significantly higher for the SPAS group (1.15 +/- 0.6 cm^2/cm^2) compared to the STROKE group (0.62 +/- 0.2 cm^2/cm^2). During the visually-guided reaching task, the SPAS group demonstrated decreased steadiness as determined by increased movement velocity when the hand was to maintain a constant position over the target (0.88 +/- 0.27cm/s vs. 0.55 +/- 0.30cm/s). There were no significant differences in movement speed or reaction time. The object hit task showed a deficit for the SPAS group in average movement area (784.0 +/- 294.1cm^2) compared to 1182.4 +/- 279.1cm^2 for the STROKE group. Conclusions: Altered position sense, higher postural instability, and less active use of the affected limb differentiated stroke survivors with and without elbow spasticity. These deficits can be potential targets for rehabilitation aimed at improving upper limb function in post-stroke spasticity.

Poster #82

The effects of the aquatic environment on upright stance control: a pilot study comparing COP displacements in water and on dry land

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ABSTRACT

The control of upright stance is essential for locomotor recovery after a spinal cord injury. Aquatic therapy is often used as a rehabilitation approach to provide postural and locomotor training. However, the literature lacks evidence of the effects of the aquatic environment on the control of posture as measured by posturography during performance in water. This study pioneered the investigation on how the aquatic environment influences the control of upright stance of able-bodied subjects, compared to performance on dry land. Seven female able-bodied volunteers were requested to stand on an AMTI waterproof force plate for 10 trials of 30-seconds each, both in water and on dry land. Participants were instructed to remain "stable" without moving their feet on the force plate, maintaining their upper limbs crossed over the chest. Visual condition was randomly assigned to all 10 trials, 5 with eyes open (EO) and 5 with eyes closed (EC). Postural sway was measured by the following center of pressure (COP) parameters: body sway area (AREA-SW), anterior-posterior (AP) and medial-lateral (ML) mean sway amplitude (MSA_{AP} and MSA_{ML}) and mean sway velocities ($MVELO_{AP}$ and $MVELO_{ML}$). Spectral analysis was performed to compute, in AP and ML directions, the main frequencies used for analysis of postural control: predominant (fpred), 95% (f95) and 50% (f50). Demographic characteristics and percentage of body mass offloading in water were also calculated. Age, height, body mass and percentage of body mass offloading of all participants ranged from 22 to 54 years, 151 to 167 cm, 55 to 70 kg, and 55% to 69%, respectively. Body sway expressed by AREA-SW, MSA_{AP}, MSA_{ML}, $MVELO_{AP}$, $MVELO_{ML}$, $f95_{ML}$ and $fpred_{AP}$ of the COP was significantly higher in water than on dry land ($p<0.05$). Subjects also oscillated more with EC than with EO ($p<0.01$), except for MSA_{ML}, V_{ML} and frequencies, which were not affected by the visual condition. The aquatic environment appears to challenge postural control by increasing the body sway compared to dry land and could be valuable to stimulate upright stance control during functional recovery after a spinal cord injury.

Poster #85

Effects of body weight unloading on ground reaction force measurements during walking

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ABSTRACT

Body weight support (BWS) system on treadmill has been used as a strategy for gait intervention in patients with different gait impairment. Considering that ground level is the most common surface used for locomotion, it is important to investigate the effects of BWS system in ground level in healthy adults prior to apply it to any protocol intervention. Therefore, the goal of this study was to investigate the effects of BWS during walking on ground level of young and healthy adults. Twenty young adults (10 males and 10 females), between 20 and 30 years old, walked on ground level in three experimental conditions as they all used harness: full weight bearing, 15% and 30% of BWS. Ground reaction forces (GRF) were acquired using two force plates (Kistler, Model 9286) imbedded in the middle of the walkway. First and second peaks, valley and impulse of vertical GRF component, deceleration and acceleration peaks and impulse of anterior-posterior GRF component were analyzed in all three conditions. The results of vertical component indicated that the magnitude of both peaks and the valley and the impulse decreased as the BWS increased. The results of anterior-posterior component indicated that the magnitude of both peaks decreased and the impulse increased as the BWS increased. Based upon these results, we may suggest that the use of BWS system during walking on ground level influences the magnitude of ground reaction force components, indicating that as the percentage of BWS increases the vertical impulse decreases but the horizontal impulse increases. Such results can be considered as an important benefit for gait intervention protocols using BWS system.

Poster #93

Cortico-muscular coherence post stroke in patients with upper limb spasticity

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ABSTRACT

Sensorimotor impairments are a major consequence of stroke. Spasticity is a neurological phenomenon associated with upper motor neuron lesions and is characterized by a velocity-dependent increase in resistance to passive stretch. In spite of the apparent disconnect between motor areas and the affected musculature, there has been little exploration into whether the functional dissociation between these sites can be quantified. Cortico-muscular coherence (Electroencephalography (EEG)-electromyography (EMG) coherence) may be a useful measure of concurrent brain and muscle activity during motor tasks and provide an indirect measure of the strength of connectivity between target sites. The objective of the study is to characterize the extent of cortico-muscular coherence in patients post-stroke with spasticity. Seven adults with ischemic stroke exhibiting unilateral spasticity of the wrist were assessed. Using a cued-response paradigm (warning and response cue), participants flexed and then extended the affected wrist back to neutral at each response cue. The task was repeated 30 times with an inter-stimulus duration of 3s and inter-trial duration of 12s. Surface EMG electrodes recorded wrist flexors and extensors from the affected arm. EEG signals were recorded with an electrode cap using the international 10-20 system. EMG and EEG signals were sampled at 1000Hz and filtered online. Coherence was computed for 2048 ms prior to and after the response cue (corresponding to temporal windows associated with motor preparation and motor execution), between the C3 or C4 electrode site and the EMG on the contralateral and ipsilateral sides. Mean peak coherence and the frequency at which the peak occurred was calculated. High frequency coherence peaks were identified in the beta (16-30 Hz) and gamma (30-50 Hz) frequency ranges. During the preparation phase, low gamma-band peaks were found in the contralateral coherence for wrist flexors (0.08 ±0.03; 32.92 ±7.54 Hz) and extensors (0.09 ±0.06; 35.16 ±8.31 Hz). High beta range coherence peaks were found during the execution for wrist flexors (0.08 ±0.03; 24.55 ±9.52 Hz) and extensors (0.07 ±0.02; 29.73 ±11.53 Hz). Ipsilateral coherence was also found in the high beta-bands with similar coherence for wrist flexors and extensors during motor preparation and execution. Relatively low levels of beta-range cortico-muscular coherence characterize upper limb post-stroke spasticity. The extent and frequency of peak coherence were consistent between ipsilateral and contralateral brain-muscle pairs. This is consistent with findings that suggest that activity in motor areas in the ipsilateral hemisphere is related to poor motor recovery after stroke.

Poster #96

Reduced perceptual-motor abilities contribute to altered obstacle avoidance in persons with visuospatial neglect

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ABSTRACT

In persons with visuospatial neglect (VSN), the walking behaviour can be influenced by the deficits in perception and in walking capacity. However, it remains difficult to assess the contribution of each factor. To understand how the perceptual deficits of VSN affect the ability to avoid moving obstacles, we designed a set of joystick-based experiments that are independent of walking capacity. Twelve participants with VSN after a stroke were tested while seated and viewing a virtual environment (VE), in a head mounted display. The VE consisted of a target and 3 obstacles, one of which randomly approached from head-on (HO) or 30° contralesionally (CL) or ipsilesionally (IL). They performed two tasks using a joystick with their ipsilesional hand: (1) a perceptuo-motor (PM) task where they pressed a joystick button as soon as they detected the movement of the obstacle and; (2) a joystick-navigation (JN) task where they moved the joystick to proceed towards the target while avoiding the approaching obstacle. In the PM task, increased detection times were observed for the CL (1.73± 1.1) and HO (1.64 ± 0.8) obstacles compared to IL ones (1.28±0.67s, $p < 0.05$). In the JN task, 5 participants showed collisions with CL obstacles while 9 collided with HO obstacles. Minimum distances tended to be smaller from the CL and HO obstacles (2.0±0.4m, 1.6±0.3m) compared to IL ones (2.4±0.3m). Greater delays in initiating navigation strategies were observed for CL and HO obstacles (2.5±0.6s, 2.2±0.5s) compared to IL obstacles (2.0±0.4s, $p < 0.05$). Longer delays in onset strategy were associated with longer detection times of obstacle in the PM task (CL: $r = 0.51$, HO: $r = 0.74$ and IL: $r = 0.54$, $p < 0.05$). Detection and responses to obstacles approaching head on and from the neglected side are altered in persons with VSN, leading to risk of collisions. These findings are consistent with results observed in locomotion while using a similar obstacle avoidance paradigm. This suggests that the colliding behaviour of persons with VSN can be attributed, at least in part, to perceptuo-motor deficits that are independent of locomotor capacity.

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Poster #99

Arm and hand control during the emergence of reaching in Infants with Neonatal Stroke

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ABSTRACT

Infants with neonatal stroke (NS) are at a higher risk for hemiplegic cerebral palsy due to focal brain injuries. The results of these injuries are most commonly impaired motor control of the contralateral arm and hand. These impairments limit participation in daily activities and independence in children with hemiplegic cerebral palsy. It is unknown how early arm and hand control is affected in infants with NS. Therefore, the purpose of this study is to identify aberrant arm and hand movements including affected and non-affect sides during early reaching in infants with NS. Sixteen infants with typical development (TD) and six infants with NS were tested from 2 – 7 months of age. All participants visited the infant lab every other week for 10 times data collections, for 220 testing points total. At each time point, infants were placed in a special-designed baby chair while a toy was presented at shoulder height for three trials at 30 seconds per trial. Reaching number, toy-touching duration and hand positions (open/close and ventral/dorsal) were measured. Repeated measures two-way ANOVA (10 visits X 2 groups (TD vs. NS)) with mixed designs were used to assess time (visits) effect and group differences of reaching number and toy-touching duration. Repeated measures two-way ANOVA (10 visits X 2 sides (affected vs. non-affected)) with within-subjects designs were used to compare reaching number and toy-touching duration between affected side and non-affected side in the NS group. Chi-square analyses were used to compare different frequencies of hand positions (open-ventral vs. others) while touching the toy. Main visit effects were observed on both the reaching number (F (5.43, 108.6) = 10.442, $p<0.001$) and toy-touching duration (F (2.9, 57.5) = 4.540, $p=0.007$). No main group effect was observed. Main side effects were observed in the NS group with less reaching number (F (1.000, 5.000) = 9.198, $p = 0.029$) and shorter touching duration (F (1.000, 5.000) = 15.791, $p = 0.001$) on the affected side. A significantly lower frequency of open-ventral hand position was observed at visit 4 in the NS group when compared with TD group. The emergence of asymmetrical reaching between affected and non-affected sides can be detected early in infants with NS. This suggests poor motor control of the upper extremity in early infancy in those at risk for hemiplegic cerebral palsy. Combining data from affected and non-affected sides in infants with NS may diminish the group difference of reaching behaviors. Furthermore, purposeful reaching position of hand (open-ventral) may not be a sensitive indicator to assess impaired upper extremity motor function during this age range.

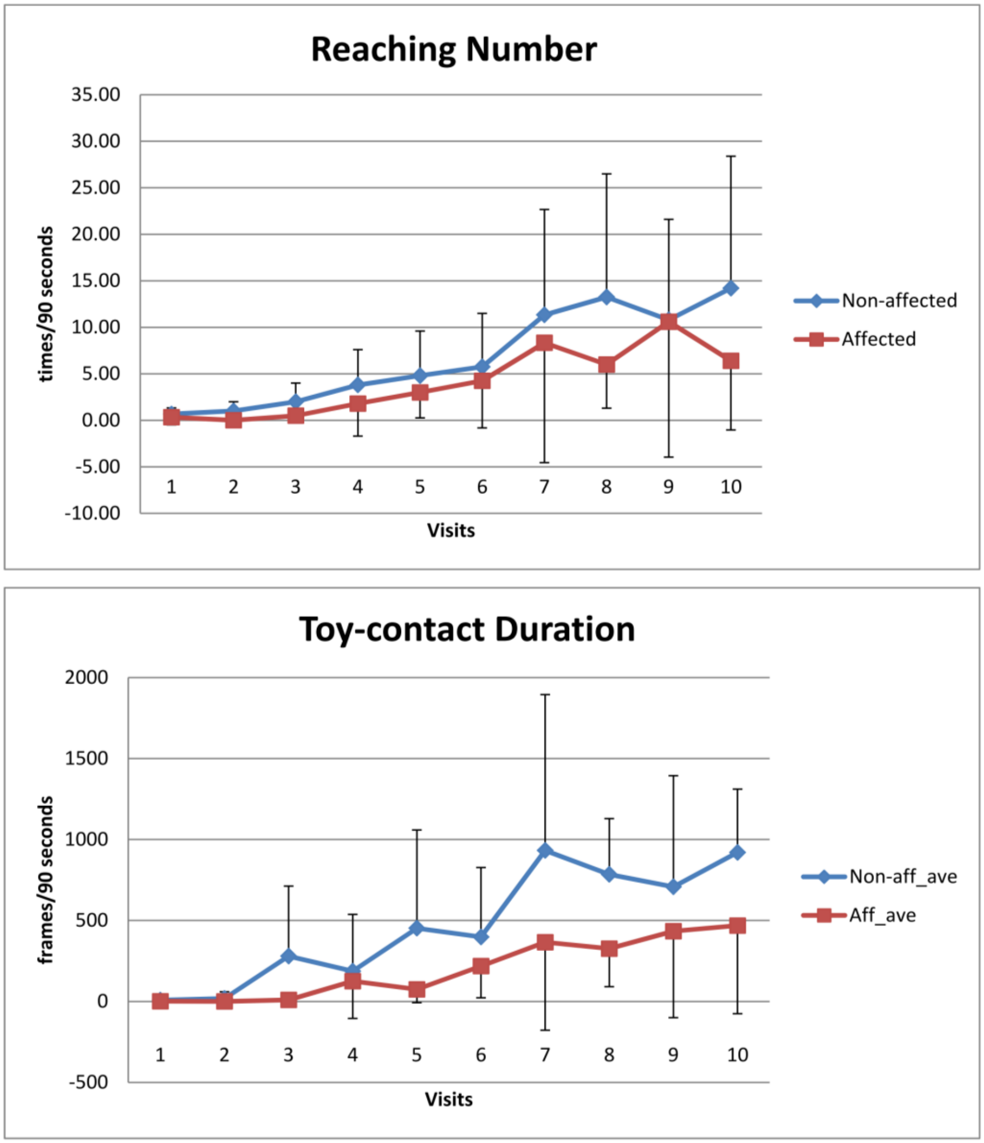

Figure 1.

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Poster #101

Role of proprioceptive information on stability during gait with healthy and hemiparetic people

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ABSTRACT

Proprioceptive stimulations through muscle vibration have been shown to alter EMG activity, joint movements, direction and speed during walking, to different extents depending on the stimulated muscle group. Despite its known role in balance control during standing, no study has assessed the role of proprioception in balance control during gait. The aim of this study was to evaluate how neck and ankle proprioceptive information affects balance during gait in persons with intact and reduced sensorimotor capacities. Fifteen participants were included in two groups: Healthy group (n=11, 43.8 (16.3) years old, Body mass index = 24.0 (4.6), Natural gait speed= 1.54 (0.17) m/s); and Hemiparetic group (n=4, 52.8 (12.4) years old, BMI= 24.3 (3.8), Natural speed= 1.09 (0.31) m/s, Chedoke McMaster Stroke Assessment median score leg = 5 and foot= 4). Continuous or phasic vibrations were applied to the non-dominant or paretic triceps surae and on posterior neck muscles during one minute walking trials at comfortable speed on an instrumented Bertec treadmill. Whole-body three dimensions kinematics was also quantified with a motion analysis system (NDI Certus). The contour of the base of support was digitalized. Postural and dynamic stability was quantified using the theoretical destabilizing and stabilizing forces, that are necessary to bring to or stop the center of mass at the limit of the base of support, respectively. These two forces are computed from kinematics and centre of pressure position within the limit of the base of support. A repeated measure ANOVA was used to compare the experimental conditions in healthy participants, and *a priori* contrasts were applied when possible to test whether any vibration condition differed from the condition without vibration. The effect of vibration was analyzed individually in stroke participants. The results were significant ($F_{(3.2)}=3.2$ and $p < .05$) regarding destabilizing forces when vibrations were applied to triceps. However, there were no significant results with neck vibrations in any condition. Regarding the stabilizing force, no significant results were found either whatever the conditions of stimulation. In the stroke group, participants only demonstrated response to the vibration of the triceps during swing phase. During a dynamic task like gait, only distal proprioceptive inputs were taken into account in our experimental conditions. Postural stability, evaluated by the destabilizing force, was increased with triceps surae vibration during gait, but was not affected by neck muscle vibration. These results are coherent with backward-leaning responses to triceps vibration in the standing position. Hemiparesis might reduce the integration of proprioceptive information during gait.

Poster #102

Strength of the trunk muscles correlates moderately with the timing of anticipatory postural adaptations

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ABSTRACT

Upright posture in human is an ongoing process of sensory-motor control. In case of predictable postural perturbations (for example quick arms rise) the controller induces anticipatory postural adaptations that precede the perturbation. The purpose of the study was to investigate the relationship between the strength of the trunk muscles and the onset timing of the anticipatory trunk stabilizing activity of the muscles. We hypothesized that there will be less delay between the trunk muscle activation and the beginning of the hand movement in subjects with stronger trunk muscles. Seventeen healthy volunteers (5 female and 12 male; age 29.6 ± 6.4 years; height 173.6 ± 7.8 cm and weight 73.4 ± 9.8 kg), without spinal or neurological disorder, participated in this study. Each subject performed 30 repetitions of fast voluntary arm raises. Activation of 4 back and 4 abdominal muscles was recorded by means of surface electromyography. On the separate session, strength of trunk flexors and extensors were measured in standing position with pelvis fixated. In all subjects trunk extensor muscles were activated before the initiation of the hand movement and before the activation of the abdominal muscles ($p < 0.001$). Results showed moderate negative correlation between the anticipatory activation of trunk extensors and strength of the trunk extensors ($r = -0.619$; $p = 0.011$) and the trunk flexors ($r = -0.498$; $p = 0.049$). The onset timing of the trunk flexor muscles activation was not statistically significantly correlated with the strength of trunk extensors ($r = -0.439$ $p=0,089$) or flexors ($r = -0.273$; $p = 0.306$). To summarize, results showed, that 38.2% of the variance of the delay, between the stabilizing muscles activity of the trunk and the beginning of the forward arm movement, can be explained by the strength of the trunk extensor muscles. These findings support the theory of similar impulse hypothesis which suggest that the onset of anticipatory postural adjustments may be a functional adaptation by the CNS to preserve postural stability.

Poster #109

Temporal coupling of bimanual skills in children with hemiplegic cerebral palsy

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ABSTRACT

Children with hemiplegia (CH) have poorly coordinated bimanual skills. Little is known about the temporal coupling of the two hands during a bimanual task, underlying pathology or relationship of this aspect of motor control to hand skills. This exploratory study examined temporal relationships of hand movements in CH using a box opening and targeting task. Comparisons were made of performance on the box opening task, corticospinal tract (CST) organisation and integrity (obtained from neurophysiological assessment) and pattern of brain activation (from neuroimaging). Ten children with hemiplegia participated (6 males,4 females; mean age 10y4mo, range 7y-16y). The task required opening the box with one hand and activate a target inside with the other; the hand (affected/less affected) used for each task element was systematically varied. Response time (triggered by a start signal), time to peak velocity, total movement time and overlap of movements (synchrony) between the hands were calculated. Performance on this task was compared before and after an intensive (60 hours/2 weeks) bimanual intervention. Transcranial magnetic stimulation (TMS) was undertaken on five children before intervention, without contra-indication to TMS, to establish whether the affected hand received a predominant ipsilateral or contralateral CST projection. TMS was applied over sensorimotor cortex of unaffected then affected hemisphere and motor evoked potentials were recorded in contracting first dorsal interosseous muscles. These children also underwent magnetic-resonance-imaging (MRI) including: 3D high-resolution anatomical images, diffusion tensor imaging and functional MRI using a simple hand clenching task. Imaging findings were compared with TMS and bimanual task performance. Preliminary results on the box opening task showed little to no overlap of movements of the two hands, with differences evident when the less affected or affected hand moves first to open the box. See Figure 1 illustrating slight overlap of movement onset (- 0.06 seconds overlap) evident if the less affected hand moved first to open the box, while no overlap evident if the affected hand moved first (+0.22 seconds delay). Following treatment, greater synchrony, as seen in typical children, was evident if the less affected hand moved first with a shortening of movement onset time and reduced variability (fewer multiple peaks of movement velocity) when the less affected hand initiated the task. Individual and group comparisons of these results with TMS and imaging findings will also be reported. These results may aid understanding of the patho-mechanisms and brain reorganization underlying the impaired bimanual coordination in children with hemiplegia and may have clinical implications regarding prognosis and management.

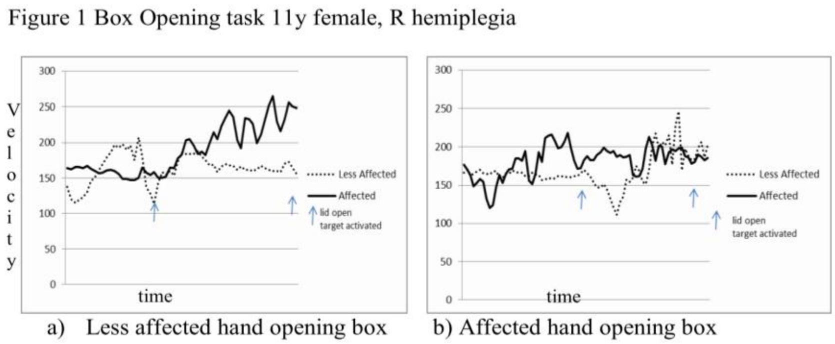

Figure 1. Box Opening task 11y female, R hemiplegia

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Poster #110

Linking brain stroke susceptibility with some movement characteristics

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ABSTRACT

This communication reports on a preliminary study investigating the possibility of using characteristics extracted from human movements to evaluate brain stroke susceptibility. One hundred and twenty subjects of both genders and of age varying between 25 and 85 years old have participated in this experiment. Fifty-seven were healthy whereas 63 had various combinations of important modifiable risk factors of brain stroke. Each subject was asked to produce 12 samples of triangular drawing constituting a 3 (triangle sizes) X 2 (rotation directions) X 2 (repetitions) factorial design. Produced movements were digitized online with a 200 Hz sampling rate and a 100 dots per millimeter spatial accuracy, using a Wacom Intuos2 tablet. Recorded signals have been studied within the conceptual framework of the Kinematic Theory of rapid human movement, using a Sigma-Lognormal curve fitting algorithm (Robust X_0) to extract neuromuscular parametric information from the subject movements. The relationship between the presence of stroke risk factors and the variability of extracted characteristics was modeled using linear regressions. Receiver Operating Characteristic (ROC) curves were used to evaluate the predictability of brain stroke risk factors from the regression parameters summarizing the information embedded in the recorded movements. Unbiased results were ensured by using a k-fold cross-validation. Our analyses show that there is a significant relationship between the presence of stroke risk factors and the state of the motor control system. The area under the ROC curve obtained for the prediction of the presence of risk factors based only on movement characteristics are as follow: cardiovascular problems (0.81), diabetes mellitus (0.82), hypercholesterolemia (0.73), hypertension (0.81), obesity (0.68) and cigarette smoking (0.70). Although both the stroke risk factors and the movement characteristics are known to be correlated with age and gender, convincing evidences have been obtained showing that the age and gender account only partially for these results. These preliminary results are a first step of a long term project aiming to better evaluating the stroke susceptibility by including, in preventive health assessment, some information extracted from a motor control analysis. Hopefully, features extracted from an evaluation of simple movements will provide a novel way to increase efficiency of brain stroke preventive actions.

Poster #114

The role of auditory feedback in improving arm reaching in chronic stroke

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ABSTRACT

Stroke is one of the leading causes of disability with less than half of patients regaining use of their arm and hand. The use of external feedback to improve motor learning is a technique that has been less studied but shows promise. This study aims to examine the role of external auditory feedback to improve reaching ability in the hemiplegic arm. We hypothesized that participants would reach more accurately when feedback is provided. Five participants in the chronic stage of stroke have been recruited thus far. Goniometers were attached to the trunk, and shoulder and elbow of the affected arm. Three different conditions were tested, all with eyes closed. In the no-feedback condition, participants made reaching movements without auditory feedback. In the rhythmic feedback condition, participants made reaching movements in synchrony with a metronome. In the continuous feedback condition, participants made reaching movements whilst hearing a consonant sound throughout the reach trajectory. If joint-coordination between the elbow, shoulder and trunk deviated from an established range (determined via passive movements), a dissonant sound is played in real-time, indicating a movement error. Participants performed 72 reaches in each condition, with 12 reaches performed without feedback before and after each condition. The 12 pre and post-condition trials were analyzed for movement duration, movement error, and range of motion (ROM) at each joint. A paired t-test was performed for each individual. Preliminary results suggest a trend at the individual level whereby movement duration was reduced after reaching with rhythmic feedback. This suggests that timing information may constrain reaches to be performed within a temporal framework. After reaching with continuous feedback, two patients with less impairment showed decreased movement error in joint coordination. Similarly, three patients with less impairment showed increased elbow and shoulder ROM with decreased trunk ROM. These findings suggest that patients with less impairment were able to use continuous feedback to decrease compensatory movements at the trunk and reduce overall movement error. Future work will include how individual differences in severity of impairment as related to lesion location and size may dictate the response to this intervention.

Poster #116

Ice skating visual stimulation primes postural response in an unexpected perturbation

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ABSTRACT

Falls are prevalent amongst older adults and various neuropathological populations. These falls are often the result of an unexpected perturbation, such as contact with an obstacle in the walking path or transition to an unpredictably slippery surface. Exercise-based falls prevention programs attempt to provide specific training of the physical skills and reflexive neuromechanisms critical in preventing falls. The purpose of this project was to examine possible contributions of dynamic visual stimulation to postural response and posture-targeted exercise. Healthy young research participants were randomly assigned to first person perspective ice skating visual stimulation (ICE - n=21, 24.0 +/- 4.4 years) or basic environmental visual cues (ENV – n=23, 21.8 +/- 1.8 years). Each group completed nine dynamic posturography trials (Equitest, Balance Master, OR USA), specifically three randomly ordered repeats of three postural challenge types – stable support (BASE), sway-referenced support (SWAY), unexpected posteroperturbation of support (PERT). Ground reaction force kinetics were resolved into group mean parameters of elliptical sway area, anteroposterior (A/P) and mediolateral (M/L) centre of pressure (CoP) displacement, and A/P and M/L CoP velocity maxima and minima, compared between groups and challenge types. Results showed that postural control measures differed significantly between postural challenge types, and that interaction existed between challenge type and visual stimulation for A/P displacement and A/P velocity minima. All postural control measures were unaffected by visual stimulation type in the BASE condition, while all measures were significantly affected by visual stimulation in the SWAY condition. In the TRANS condition, the posture-corrective A/P velocity minimum achieved immediately post-perturbation was selectively and significantly increased in the ICE condition, suggesting that ice skating visual stimulation primed postural response in a 'quiet standing' condition for an unexpected posterior perturbation of the feet. The potential for this priming was pursued in a case-control study with a 38 year old male Parkinson's disease patient, who showed significantly improved postural control while conducting balance control exercises in posturally challenging conditions with first person perspective ice skating visual stimulation.

Poster #120

The effect of cooled gel-packs on the knee joint position sense in healthy individuals

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ABSTRACT

Proprioception plays an important role in the complex mechanism of the knee joint control. Contemporary sport's disciplines impose on athletes extremely high physical demands. In addition, many of today's competitions are set in locations experiencing excessively low temperatures. Physiotherapy and various biological renewal/rejuvenation methods apply treatments that involve lowering locally the temperature before physical activity. Published results on how the cryotherapy affects joint position sense (JPS) are not uniquely conclusive and sometimes contradictory. The main objective of this study was to investigate the impact of the cooled gel-packs on the JPS of the knee joint in healthy human participants. The study group was comprised of 40 randomly chosen students (age: *21.4 ±1.9* years, height: *171.3 ±9.2* cm, weight: *63.2 ±12.7* kg, BMI: *21.4 ±2.5*) of Physical Education. The local cooling was achieved with the use of commercial 3M™ NEXCARE™ gel-packs (-*2 ±2.5*°C) applied simultaneously over the knee joint and the frontal part of quadriceps femoris muscle of the dominant leg for 20 minutes. Evaluation of the JPS was done with the use of BIODEX System 4 Pro® apparatus. Active Joint Position Sense test was conducted. Measurements were taken before and immediately after application of the gel-packs. Temperatures of the skin surface (T1-thight, T2-knee joint), the gel-packs (T3), and the surroundings (T4) were measured with the use of K-type thermocouples and digital meter YC-747UD. Repeated measures analysis of variance (ANOVA) did not show any statistically significant changes of the JPS under application of the cooled gel-packs for all analyzed variables; the JPS's absolute error ($p=0,3051$), its relative error ($p=0,6031$), and its variable error ($p=0,8161$). The results indicate that the local cooling enforced by the use of cooled gel-packs does not affect the proprioceptive acuity on the knee joint. This seems to suggest that local limited cooling before physical activity does not present neither health nor injury risk.

Poster #123

The application of rTMS to improve motor impairment in Multiple Sclerosis: a pilot study

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ABSTRACT

Multiple Sclerosis (MS) is a disease affecting the basic myelinating structures of the central nervous system with motor symptoms that fluctuate over time. Preliminary evidence suggests that cortical disinhibition in some MS patients may serve as a compensatory mechanism to promote preservation of function to counter disease progression. Notably, prior research has demonstrated the capacity of repetitive transcranial magnetic stimulation (rTMS) to reduce levels of intracortical inhibition using paired-pulse techniques. We therefore hypothesized that impairment in motor function would be reduced through the application of rTMS over the motor cortex. The objective of this pilot randomized control study was to evaluate the effects of rTMS on motor function and intracortical inhibition among MS patients with demonstrated motor impairment. Twenty-seven patients with relapsing-remitting and secondary-progressive MS were recruited while in remission and randomized to real (n = 14) or sham (n = 13) rTMS groups. Application of rTMS was over the motor cortex contralateral to the dominant hand in 20 1-second trains at 10-Hz frequency and 90% of resting motor threshold. Intracortical inhibition (paired-pulse and cortical silent periods) and motor performance (9-hole peg test) in the dominant and non-dominant hands were measured immediately before and after intervention. Results from the group receiving rTMS demonstrated no change in either paired-pulse MEP amplitudes (average decrease of 6% relative to baseline MEPs) or cortical silent periods (average increase of 4.14 ms, 95% CI [-32.07, 40.36]). Similar null findings were observed in the sham rTMS group. Average time to complete the 9-hole peg test demonstrated no change between pre- and post-intervention measures for both the real (dominant = 0.49 sec [-4.04,5.03] , non-dominant = 0.53 sec [-8.09,7.03]) and sham rTMS group (dominant = 0.16 sec [-3.70,4.01], non-dominant = 1.42 sec [-7.83,10.76]). Therefore, administration of rTMS produced no significant changes in either intracortical inhibition or motor functioning. As such, results from this study do not support a therapeutic role for rTMS in reducing motor impairment among patients with MS.

Poster #126

Are TMS-derived measures reliable markers of neural plasticity in people with stroke?

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ABSTRACT

Transcranial Magnetic Stimulation (TMS) applied over the motor cortex is a non-invasive method of measuring corticomotor excitability. TMS-derived measures are routinely employed as a marker of neural plasticity following rehabilitation. Standard protocols for TMS often require the participant to generate a low level of muscle activity; however people with motor impairment following stroke have difficulty generating and sustaining a consistent level of muscle activity during low level contractions. This may contribute to the variance and poor inter-session reliability reported for TMS measures in the lower limb in this population. Muscle activity in people with stroke is more consistent during functional motor tasks. Therefore, the aim of this study was to evaluate the reliability of TMS measures of corticomotor excitability during a low level contraction and during walking in healthy people and people following stroke. People with chronic stroke who had walking disability (n=12) and healthy age-matched controls (n=14) were recruited for this study. A repeated measures cross-sectional design, with 7 days between sessions, was used. TMS measures of corticomotor excitability of the soleus muscle were evaluated during a static low level contraction and during treadmill walking. The intra-session and inter-session reliability of motor evoked potential (MEP) amplitude and root mean square (RMS) were determined using the intra-class correlation coefficient (ICC) and typical percentage error (TPE). Static contraction intra-session measures demonstrated excellent reliability (MEP ICC; Control =0.87, Stroke =0.84, RMS ICC; Control=0.85, Stroke=0.81) and moderate within-subject variability (MEP TPE; Control =65%, Stroke=40%, RMS TPE; Control=44%, Stroke=38%) in both groups. Static contraction inter-session measures demonstrated excellent reliability and moderate within-subject variability in the control group (MEP; ICC=0.83, TPE=44%, RMS; ICC=0.90, TPE=29%) and poor reliability and large within-subject variability in the stroke group (MEP; ICC=0.29, TPE=150%, RMS; ICC=0.22, TPE=79%). Treadmill walking inter-session measures demonstrated poor reliability and moderate within-subject variability in the control group (MEP; ICC=0.31, TPE=49%, RMS; ICC=0.30, TPE=47%) and excellent reliability, and moderate within-subject variability in the stroke group (MEP; ICC=0.94, TPE=51%, RMS; ICC=0.94, TPE=46%). In summary, TMS measures of corticiomotor excitability taken during a motor task demonstrate better inter-session reliability and less within-subject variability than measures taken during a static contraction in people with stroke. Therefore, whilst TMS measures taken during a static contraction maybe a suitable measure of immediate intra-session neuroplastic changes; studies which aim to measure long term neuroplastic changes, such as in response to a stroke rehabilitation programme, should consider TMS measures taken during a relevant functional motor task.

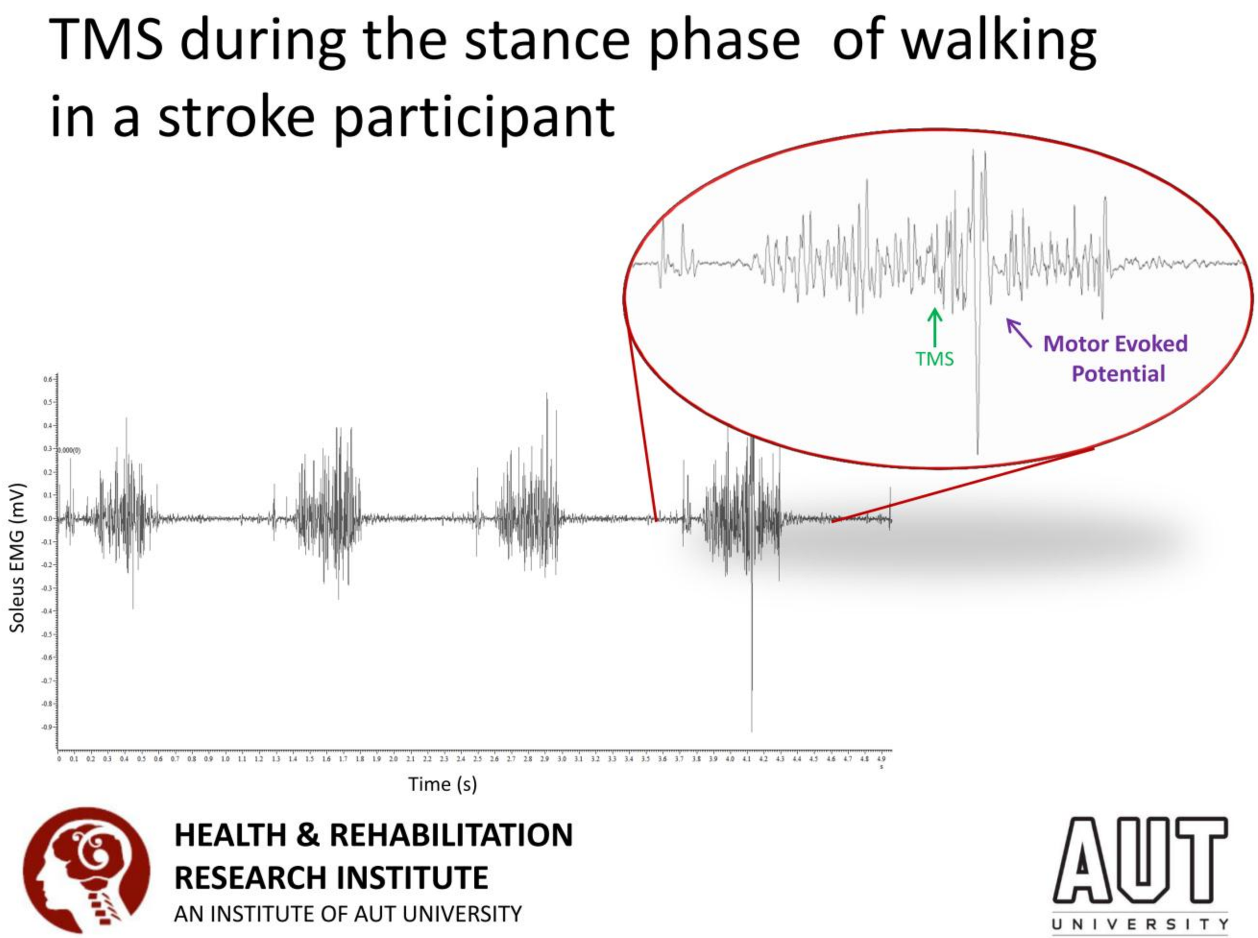

Figure 1. TMS during the stance phase of walking in a stroke participant

Poster #128

Shoulder – trunk coordination using the arm-plane representation for reaching movements in patients with stroke

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ABSTRACT

Reaching movements in patients with stroke are often accompanied by excessive trunk and/or scapular movement to compensate for deficits in the ability to extend the hand to the target. Reaches of the paretic arm are also characterized by abnormal muscle co-activation of shoulder flexors, shoulder abductors and elbow flexors, which is part of the stereotypical abnormal flexor synergy. The goal of this study was to describe the role of the flexor synergy during reaching in individuals with stroke with respect to the appearance of compensatory trunk movement. We analyzed the co-variation of shoulder and elbow movements, expressed as the arm-triangle formed by the proximal and distal arm segments, with respect to trunk movement during goal-directed reaching. Method: Sixteen adults with right post-stroke hemiparesis and 8 healthy age-matched controls reached in three target directions (ipsilateral, midline, contralateral; 14 trials/target). Data were recorded from 4 passive reflective markers placed on the arm and three orthogonal markers placed on a rigid exoskeleton attached to the subject's back (trunk). Arm-plane (plane defined by the arm triangle) and trunk motion was quantified along with endpoint motion and joint angles. In addition, we analyzed relative trunk and arm-plane motion onset and relative peak velocity times. Data were analyzed with a mixed-design ANOVA with Target and Group as within- and between-subject factors. Results: For all target directions, patients used significant trunk movement compared to negligible trunk movement in controls. For arm-plane motion, temporal and spatiotemporal variables (time to peak velocity, smoothness) differed between groups while spatial variables (path length and range) were similar. The spatial similarity was present despite different individual joint (shoulder, elbow) excursions. Arm-plane movement onset preceded trunk movement onset in stroke subjects while the opposite was found in controls. Arm-plane movement started earlier with respect to trunk movement in moderate-severe compared to mild stroke subjects. Despite the difference in segment recruitment, for all target directions and all subjects, the time of arm-plane peak velocity preceded that of the trunk. However, the time interval between arm-plane and trunk peak velocities was shorter for control than for stroke subjects, and shorter for mild compared to moderate-severe stroke subjects. Discussion: Differences in arm-plane-trunk onset times suggest that stroke subjects used a different joint recruitment pattern to elevate and extend the arm during reaching compared to controls. The differences in peak velocity times suggest that movements in moderate-severe stroke subjects were more segmented and characterized by reduced temporal inter-joint coordination. Overall, our results suggest that excessive trunk motion in stroke patients is related, at least in part, to impairments in temporal arm joint recruitment and inter-joint coordination.

Poster #134

Post-adaptation kinetic changes following walking on a split-belt treadmill with asymmetrical belt speeds in healthy individuals

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ABSTRACT

Recent studies have shown a reorganization of the locomotor pattern after walking on a split-belt treadmill. The leg on the faster belt presented a longer step length compared to the other leg when both belts returned to the same speed, therefore resulting in asymmetrical step length in healthy controls and reduced step length asymmetry in post-stroke individuals. However, no study has ever reported the biomechanical causes of these changes. The aim of this study was therefore to characterize the kinetic aftereffects of the lower limbs following a perturbation on the dominant side imposed by a split-belt treadmill in healthy individuals. Twelve healthy individuals (≥65 years) participated in the study. Participants walked under 3 conditions: 1) with the speed set 30% slower than their comfortable speed (baseline); 2) with the speed of the right belt set at twice the speed of the left belt for 6 minutes (adaptation); and 3) with both belts set at baseline speed (post-adaptation). Kinematic data were obtained using the Optotrak system and ground reaction forces were collected via the instrumented split-belt treadmill (Bertec FIT). An inverse dynamics approach was used in conjunction with biomechanical analysis to quantify the net moments of the lower limb joints. Baseline and post-adaptation data from 5 gait cycles were compared with the Wilcoxon test for paired samples. The preliminary results (n=8) revealed that the joint moments for both lower limbs differed between baseline and post-adaptation performance. For the right limb, the plantarflexor moment was reduced by 20% between 25% and 60% of the gait cycle ($p = 0.012$). The knee moment was also significantly modified towards extensor moment compared to baseline, while a slight increase of the extensor moment at the beginning of the stance phase was observed at the hip ($p = 0.017$). For the left limb, a slight increase of the plantarflexor moment was observed during the stance phase ($p = 0.035$), while the knee extensor moment only increased during early stance ($p = 0.025$). These results showed that motor adaptation occurs in both limbs due to the bilateral kinetic changes observed post-adaptation, which could explain the step length asymmetry previously observed in the post-adaptation period among healthy individuals. The reduction of the right plantarflexor moment and the increase of the left plantarflexor moment could explain this asymmetrical step length since one of the most important factors in generating step length is the forward propulsion of the contralateral limb during stance by the plantarflexors. The increased plantarflexor moment on the left side is interesting as it is often reduced in hemiparetic gait. Future studies in stroke individuals will help determine whether this perturbation can be used to train the plantarflexors and better understand the biomechanical changes associated with step length asymmetry. We thank CIHR, MENTOR, OPPQ, REPAR and SMRRT for financial support.

Poster #138

Inter-rater and intra-rater reliability of shoulder position sense measurement tools

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ABSTRACT

Position sense plays and important role in providing stability to the shoulder joint. When position sense is compromised, the joint can become unstable and consequently susceptible to muscular or ligamentous injuries. An injury to the shoulder joint or even fatigue of the muscles around the joint can also produce deficit in position sense. Therefore assessment of position sense before and throughout the rehabilitation process can guide therapists and patients toward achieving better outcomes. Most of the available position sense measurement tools are only used in the research setting, as they are both cumbersome and costly. Accordingly, the purpose of this study was to estimate the inter-rater and intra-rater reliability of three measurement tools that are simple to use and at the same time affordable for all clinicians. These tools were: laser pointer, inclinometer and goniometer. Twenty-five healthy subjects were asked to flex their dominant shoulder with the elbow in full extension and forearm and wrist in neutral position (thumb facing upward), while their eyes were closed and their contralateral arm was resting along their body. They were told to stop when they reached to a pre-established target. They then had to reproduce the movement from memory, with the difference taken as error in position sense. The laser pointer was attached to the arm, and the laser light projected on a vertical scale in front of the subject was used to infer shoulder angle. An inclinometer was attached to the arm, just above the laser pointer. The experimenter aligned the segments of the goniometer with the arm and trunk segments and the pivot with the head of the humerus, according to usual clinical procedures. Subjects actively reproduced different shoulder angles within three different ranges (55º±10º, 90º±10º and 120º±10º) three times each. Two experimenters tested each subject separately for inter-rater reliability. For the intra-rater reliability, subjects were tested again 24 hours after the first session. The mean of three values was calculated, and intra-class correlation coefficient (ICC) was used to estimate the inter-rater and intra-rater reliability. The results showed that the laser pointer has the highest reliability (inter-rater=0.86, intra-rater=0.78) followed by the inclinometer (inter-rater=0.67, intra-rater=0.70) and the goniometer (inter-rater=0.5, intra-rater=0.6). The result of this study showed that the laser pointer technique has "excellent" reliability and the inclinometer and goniometer have "fair to good" reliability in the measurement of shoulder position sense. The laser pointer technique is very simple and can be used in any physiotherapy clinic. Having a simple and reliable tool in hand can facilitate the ongoing assessment of shoulder position sense throughout the rehabilitation process, which might eventually lead to better therapeutic outcomes.

Poster #139

Twenty five years experience at the Sainte-Justine Hospital of selective dorsal rhizotomy based on clinical observations instead of intraoperative electrophysiological monitoring

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ABSTRACT

Selective dorsal rhizotomy (SDR) is a surgery performed between spinal nerves L2 and S2 to reduce lower limb muscle spasticity. In children with diplegia cerebral palsy (CP), this intervention is generally implemented to improve gait. Usually, the choice of the level and the amount of rootlets cut is based on the muscle electrophysiological response evaluated during the surgery. However, this method remains criticized to assess muscular spasticity (Peacock et al. 1990, Weiss and Schiff 1993). Since twenty-five years in our hospital centre, the levels and ratios of rootlets cut have exclusively been defined on the basis of clinical observations resulting in a less invasive intervention. To date, SDR has been practiced in 276 children. The aim of this retrospective study was (1) to describe the decision process based on patient clinical evaluation, and (2) to report the effectiveness of this method to improve gait. Since the late 80's, patients' eligibility to the surgery, the spinal cord level and the ratio of rootlets cut have been determined by a single physiatrist. His decision tree is based on clinical evaluations (Figure 1). The Edinburgh Visual Gait Score (EVGS ; Read et al. 2003) was used to evaluate gait. Video recordings were analyzed in 33 children with spastic diplegia CP before and two years after SDR. Student Test was used to compare means. The total EVGS scores before and two years after SDR are significantly different ($p<0.001$). Children showed significant differences before and after SDR concerning 13 of the 17 EVGS observations. The initial contact, the heel lift, the maximal dorsiflexion in stance and swing, the knee peak extension stance and the knee terminal swing significantly improved after SDR ($p<0.001$). The SDR based on clinical observations improve gait. The decision tree results in an appropriate patient selection and SDR parameter choices. Further studies are needed to compare clinical and electrophysiological-based approaches.

Poster #153

Trunk muscles activity during different upper limb exercises in anticipatory postural adjustments times: a quantification for periodization of therapeutic exercises

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ABSTRACT

Anticipatory postural adjustments (APAs) are postural muscle activations or inhibitions performed toward opposite to those produced by the reactive moments generated by limb. APA generation can be affected by the task variability's. Adequate dynamic stability of the spine is essential to safeguard the musculoskeletal system against injuries. Since scientific knowledge about the therapeutic strategies for using appendicular exercise for stability spine training require more studies, the aim of this study includes the evaluation and comparison of electromyographyc (EMG) activity in postural muscles of upper limb exercises performed in different conditions. Nine healthy subjects, men and women physically active and without any known neurological or musculoskeletal disorder participated in the experiment. Procedures were performed for estimating load with 10 Maximum Contractions (MC) of upper limbs. Kinematic and pressure center displacement data were collected and synchronized during each exercise (unilateral abduction, bilateral abduction, unilateral flexion and bilateral flexion), that were performed in 3 different situations: self-selected speed (slow), greater velocity possible (fast) and using a dumbbell (load). Surface EMG measured muscle activity for each 14 muscles, on both sides (anterior deltoid, middle deltoid, rectus abdominis, internal obliques, lower erector spinae, lumbar longuissimus, ileocostalis and multifidus). The obtained EMG signals were analyzed using customized software. Onset time (T0) was defined and EMG signals were amplified, digitized, full-wave rectified, low-pass filtered and all signals were then normalized to the MVC values. Root Mean Square (RMS) values were calculated and the average RMS for each muscle during different APA times was obtained. Repeated measures ANOVA, was performed and the statistical significance was set at $p \leq 0.05$. The comparison of EMG activity of the studied muscles during different exercises showed there are interactions among exercise, muscle and situation (velocity and load). There are no differences in muscle activity in the different stages of APAs and between exercise and laterality, but muscles from both sides presented greater values of RMS in bilateral flexion, when compared with unilateral or bilateral abduction. Posterior trunk muscles showed higher activity in bilateral flexion than all other situation while anterior muscles presented higher activity than posterior muscles in abduction exercises. Among the studied situations, the highest general muscle activity was found during bilateral flexion with load. Velocity of movement and load are critic to determine the exercise intensity for core stabilizers muscles. Simple therapeutic exercises are effective in activating both abdominal and paraspinal muscles, but more studies are necessary to provide information for exercise training periodization of different populations.

Poster #159

Dissociation between EMG activation ratio and active range of motion in individuals with wrist flexor spasticity

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ABSTRACT

Upper limb spasticity following stroke is characterized by a velocity-dependent increase in resistance to passive movement, leading to increased stiffness of the affected joints and difficulty performing volitional movements. As such, a reduction of upper limb spasticity is often an important outcome of post-stroke rehabilitation as a means of restoring independence. Typically, the aim of spasticity management is to reduce spasticity of the affected muscle and increase function of its antagonist. While measurements of active range of motion (ROM) are used as an outcome measure to assess treatment efficacy, they are typically not paired with measures of muscle activation in the affected muscle or its antagonist. Quantitative measures of muscle activation could provide additional information regarding the mechanisms that contribute to the resolution of spasticity over time. The objective of this study was to characterize the correspondence between active range of motion and EMG in patients with wrist flexor spasticity. This study analysed a subset of four participants with wrist flexor spasticity after stroke. Thirty trials of wrist flexion and extension were performed. Each trial began in a neutral position. In response to an auditory tone, participants were asked to perform rapid wrist flexion, followed by extension to the neutral position. Surface EMG electrodes were placed on the wrist flexors and extensors of the affected limb. EMG signals were sampled at 1000Hz and filtered online at 10-1000Hz. Wrist joint position (active ROM) was measured with a potentiometer and was used to separate flexion and extension movements. The RMS amplitude of EMG was determined during each phase of movement. The ratio of agonist: antagonist EMG was then calculated in each direction of the movement. EMG ratios ranged from 0.88 to 3.14 in flexors and 1.22 to 3.47 in extensors, illustrative of patterns of muscle co-contraction and reciprocal patterns of activation. Active ROM ranged from 23° to 76° in flexion and 12° to 79° in extension. Overall, the level of activation was not associated with the ROM. The purpose of this study was to investigate the relationship between EMG activation profiles and behavior (active ROM). The results of this study show that EMG activation ratios were not associated with active ROM, thus highlighting the added value of quantitative EMG in characterizing motor recovery after stroke.

Poster #160

Patterns of muscle coordination during stepping responses post-stroke

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ABSTRACT

Regaining ambulatory balance is critical for individuals recovering from stroke. A stepping reaction is often the first line of defense to prevent a fall. The purpose of this study was to investigate the motor control strategy of stepping responses using Principal Component Analysis (PCA) in persons post-stroke compared to healthy age- and sex-matched controls. Seventeen subjects, 13.3 ± 3.6 weeks post-stroke, and 17 controls were tested. Surface electromyographic (EMG) signals were recorded from the tibialis anterior (TA), soleus (SOL), rectus femoris (RF) and biceps femoris (BF) muscles bilaterally. Subjects were instructed to lean forward at the ankle and take a single step to regain balance. Each subject performed fifty steps with each leg. A total of 100 steps for each subject were entered into the PCA. Separate one-way ANOVAs were used to determine group differences (control, paretic, non-paretic) for the stepping and stance leg. In the stepping leg, ten Principal Component (PC) waveforms were identified, explaining 76.5% of the variance in muscle activation patterns across groups. The first PC (PC1) explained 43.2% of the variance and no group differences were found. In PC1, the BF and SOL EMG intensity increased at step initiation. The BF and SOL activity lowered at mid-step, while the TA and RF EMG intensity increased. In the latter half of the step, the intensities of the RF, SOL and BF increased, reaching a peak at foot contact. In the first ten PCs, seven had significant group differences in the mean loading scores ($p<0.05$). Muscle activation patterns characteristic of the paretic leg included an earlier onset of TA closer to step initiation and an earlier onset of BF and SOL muscles towards mid-step. In the stance leg, ten PC waveforms were identified, explaining 77.0% of the variance of which PC1 explained 44.4%. In PC1, the paretic BF and SOL muscles in the stance leg were active at step onset, and the paretic RF and TA were active in the latter half of the step. The loading scores of the ten PCs had significant group differences ($p<0.05$), yet no single muscle activation pattern was unique to the paretic leg. The muscle activation patterns of the paretic BF and SOL showed reduced activity at step onset or a delay of BF and SOL onset to mid-step, whereas TA and RF had less activity at mid-step but increased in intensity late in the step. The results suggested that adaptive motor strategies in the stepping leg may compensate for reduced EMG amplitude with an earlier TA onset to ensure foot clearance and increased BF amplitude for knee flexion. In the stance leg, no muscle activation patterns were unique to the paretic leg. These data demonstrate that PCA provides a powerful analytical technique to identify altered motor control strategies that may be useful in understanding stepping reactions after stroke.

Poster #166

Ankle plantarflexor activity during standing perturbations in people following stroke as measured with high density surface electromyography

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ABSTRACT

Sensorimotor deficits after stroke contribute to an increased risk of falls. The ankle plantarflexor muscles are essential for maintaining postural stability in quiet stance. How impairment in the plantarflexors after stroke impacts the motor response to perturbations of balance is not well understood. The purpose of this study was to conduct a comprehensive examination of the ankle plantarflexor muscles in response to external perturbations using high density surface electromyography (HDsEMG). Four people with chronic stroke (64-81 years of age, 3 males) with mild to moderately-severe levels of motor impairment participated. Participants stood with each foot on a separate force platform. Anteriorly-directed external loads were dropped by a cable and pulley system attached to a belt around the participants' pelvis. Incremental loads of 1% body mass were applied every 25-30 s until a total of 5% body mass was reached. The response to the load drop was analyzed in two epochs: 1) the dynamic response to load (for 1 s, starting 250 ms before load drop) and, 2) the static maintenance of standing balance (15 s between loads). The anterior-posterior centre of pressure (COP) displacement was measured simultaneously with HDsEMG from the soleus (SOL) (24 electrode grid, 2 cm interelectrode distance), medial (MG) and lateral gastrocnemius (LG) (20 electrode grids each, 1 cm interelectrode distance) of both the paretic and non-paretic leg. Anterior-posterior centre of gravity (AP-COG) was calculated from the COP displacement. HDsEMG signals were analyzed in bipolar configurations resulting in 18 EMG signals from the SOL muscle and 16 from each of the MG and LG muscles; the root mean square amplitude (RMSamp) was calculated. Correlations between the EMG signals and AP-COG were determined during the static maintenance of standing balance. RMSamp of each bipolar EMG signal from the LG and SOL was significantly decreased in the paretic leg compared to the non-paretic leg during the initial response and maintenance at each level of load ($p < .05$). While the RMS amp of the MG EMG was lower in the paretic than the non-paretic legs in both epochs after the first two loads, during maintenance of loads of 3-5% body mass the MG EMG signal was not significantly different between legs. Both the paretic and non-paretic plantarflexors demonstrated moderate correlations between muscle activation and the AP-COG during maintenance of standing balance after each load. The amplitude of muscle activation of the plantarflexor muscles of the paretic leg in response to perturbations is decreased in individuals after stroke. Despite the lower EMG activation, the EMG of the paretic plantarflexors demonstrated similar correlations with the AP-COG. These findings may indicate that the fundamental mechanisms of postural control are intact, even with moderately-severe muscle impairment but are dampened in magnitude.

Poster #168

Analysis of children with cerebral palsy walking with partial body weight support system on static surface

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ABSTRACT

Gait is a key issue among different disorders of movement development and function of children with cerebral palsy (CP). Considering that walking is an important functional goal for these children, a strategy that promotes the best benefits is a challenge. Among different strategies for walking development of children with CP, partial body weight support (PBWS) has become very common. However, PBWS is often used as these children walk on motorized treadmills. If we considered task-specificity for gait training, we could suggest the employment of PBWS as children with CP walk on static surface (i.e. floor) instead of dynamic surface (i.e. treadmill). In this way, this study investigated some walking gait characteristics in terms of ground reaction force (GRF) components and spatial-temporal measurements of children with CP walking with different percentages of PBWS on static surface. Three children with diplegic CP (mean age, 8 years old) were videotaped as they walked freely and with PBWS at three different percentages of body unloading (0, 15 and 30%) on a walkway with two force plates imbedded in the middle of it. First and second peaks and valley of vertical GRF component, and impulse of anterior-posterior GRF component; stride length, duration and velocity, step length and cadence were analyzed in all conditions. All children were able to walk using PBWS system, and apparently, when they walked with 15% of body unloading, they presented the magnitude of first peak closer to the second peak, as in the remaining conditions the magnitude of both peaks were discrepant. On the other hand, these children presented similar results for the spatial-temporal gait measurements. According to these results, it seems that walking with PBWS on static surface is a strategy that should be taken into account as one thinks of training strategies for walking of children with CP, and in this case, 15% of body unloading seems to be the most suitable condition to start with gait training of children with CP.

Poster #172

Postural stability is reduced in people with Multiple Sclerosis due to walking-imposed fatigue

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ABSTRACT

Among the symptoms reported most limiting by individuals with multiple sclerosis (MS) are impaired balance and symptomatic fatigue. While it is logical that these two symptoms may be interrelated, the impact of fatigue due to activities of daily living (ADL) on balance is not yet known. We have previously reported greater postural sway and reduced stability following muscular fatigue (isometric/isokinetic protocol) in individuals with MS compared to those without (Van Emmerik, 2010). It is currently unknown whether a similar relationship exists with modest increases in fatigue resulting from an activity of daily living such as walking. Thus, the purpose of this study was to determine whether a prolonged bout of walking has a greater impact on balance during postural tasks in people with MS (PwMS) compared to those without MS. Seven PwMS (43±12 yrs, 1.67±0.7 m, 73.2±16.3 kg; 6F/1M) and 10 age-matched controls (CON; 42±12 yrs, 1.69±0.9 m, 74±14.6 kg; 7F/3M) participated in this study. Participants performed postural tasks (quiet stance, and fixed distance and maximal reaches) prior to and following 30 minutes of treadmill walking at a range of speeds (0.6-1.4 m/s and self-selected speed). Individuals rated their symptomatic fatigue at baseline and following walking using a visual analog fatigue scale. Kinematic data were recorded using an eight camera passive marker system (Qualysis AB) and kinetic data were recorded using two forceplates (AMTI), one under each foot during the postural tasks. The net center of pressure was computed from the forceplates and analysed using a time to contact (TtC) analysis to assess postural stability. Following prolonged walking PwMS demonstrated greater reductions in TtC values than did the CON group during the most challenging postural task of maximal backward reaching (Fatigue X Group: P=0.04). This indicates that PwMS demonstrated a greater reduction in postural stability that may be related to increased symptomatic fatigue (Fatigue: P < 0.0001) following prolonged walking. PwMS demonstrated higher TtC values than the CON group for the maximal backward (P=0.009) and forward (P=0.03) reaches in the frontal plane only. However, maximal reach distances achieved by PwMS compared to controls tended to be shorter (Backward: P=0.2; Forward: P=0.008). These findings suggest that PwMS place a higher priority on stability, particularly in the frontal plane, than maximal reach distance; whether this relates to fall-related fear or specific disease-related limitations is unknown. The current results indicate that postural stability is reduced in PwMS following a common ADL activity such as walking, thus individuals with MS should be counseled on the increased likelihood of balance loss with heightened fatigue, even at relatively low levels.

Poster #175

Multiscale Entropy Identifies Postural Control Changes in Persons with Multiple Sclerosis

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ABSTRACT

Multiple Sclerosis (MS) is a chronic auto-immune disorder characterized by demylenation of neurons of the central nervous system. Increased fall rates, resulting from impaired postural control, are common in the MS population. Previous reports have shown that persons with MS restrict their center-of-pressure (CoP) excursions during maximal reaching and leaning tasks (Van Emmerik, et al., 2010). These differences in reaching distance may have confounded previously reported changes in CoP complexity (Busa et al. *In Preparation*). Examining submaximal reaches as a paradigm for comparing MS and healthy controls (CON) may serve as a method to assess the impact of MS during challenging postures, without the confounding factor of different reach distances. The purpose of this study was to examine differences in the control of postural fluctuations between persons with MS and healthy controls. Multiscale Entropy (MSE) or complexity analysis was used to assess these differences in CoP control in anterior-posterior (AP) and medio-lateral (ML) directions. We hypothesized that MSE is reduced in MS compared to controls in both quiet standing and a more challenging reaching task. Eight persons with MS (7 female, 1 male) and ten age, height, weight and sex-matched controls completed the testing procedures. The MS subjects had minimal functional impairment (patient determined disease steps (PDDS) range 0-3). Three postural tasks were examined: quiet standing and fixed distance forward and backward reaches. Reach distances were controlled to a distance 20% (forward) and 10% (backward) of arm length and each posture was maintained for 30s. Multiscale entropy was determined across 30 time scales (range .01-.25s). Effect size (ES) statistics were used assesses differences between MS and CON populations. Quiet standing revealed moderate effect of reduced complexity in persons with MS compared to CON in the AP direction (ES = .71). The backward reach revealed a strong group effect, demonstrating reduced complexity in both the AP and ML in the MS group (ES = .74 and 1.0, respectively). Additionally, the forward reach condition revealed reduced ML complexity in the MS group (ES = .68). These results support the hypothesis that persons with MS display reduced complexity of postural control compared to those without MS. These results are in agreement with the loss of complexity hypothesis; stating that reduction of functional degrees of freedom due to aging or disease can ultimately lead to frailty and loss of adaptability. The use of multiscale entropy to detect differences between MS and CON in this study is novel, as the MS cohort examined is highly functional and in some cases display little to no functional impairments (PDDS < 3). The sensitivity of the MSE analysis offers a promising new tool that may afford detection of complexity differences along a continuum of MS related functional impairments.

Poster #178

Muscular co-activation and joint torque during elbow flexion-extension in healthy adults: towards a tool to quantify spasticity during voluntary movement

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ABSTRACT

Introduction: Children with cerebral palsy (CP) experience movement disorders caused by altered muscle tone, leading to abnormal muscle synergies and co-activation (CA). To properly assess the motor behavior during active movements, both biomechanical and electromyographic (EMG) data must be collected. Although several studies focus on lower limbs in CP children during gait, very few studies exist to evaluate the upper limb voluntary movements, which are nevertheless essential to a complete functional evaluation. Consequently the objective of this study is to analyze the elbow joint torques (JT) and CA in typically developed (TD) adults, and further to compare these results to TD and CP children. Methods: 15 TD adults, 15 TD children, and 15 CP children with a Manual Ability Classification System level between 1 and 3, performed 5 cycles of each of the following voluntary movements: elbow flexion-extension (F/E) and pronation-supination (P/S) at different frequencies (0.35Hz, 0.50Hz, 0.65Hz), hand-to-mouth and hand-to-hip. This abstract presents the preliminary results of F/E in 8 healthy adults. The results of the complete database are currently being analyzed and will be presented at the conference. Kinematics was recorded by a VICON motion capture system tracking 29 retroreflective markers placed on anatomical landmarks of the upper limb. The JT were obtained using a multibody dynamic model of the upper limb developed by M. Raison et al (2011). Surface EMG of the six main superficial muscles responsible for F/E and P/S was recorded and filtered according to the European SENIAM recommendations, from H.J. Hermens et al (1999). Muscle activation was determined by normalizing EMG signals with respect to isometric maximum voluntary contractions. CA was then defined by the ratio between triceps (antagonist) and biceps (agonist) activations. Reproducibility of JT and CA results, influenced by the protocol and the model, was evaluated in healthy adults. Results and discussion: Preliminary results show very good agreements of JT and CA (Bland-Altman plot) between intra-test F/E cycles, enabling their averaging before inter-test analyses. The elbow JT and CA both had the same global pattern regardless of the participant or the frequency (Fig. 1 a and b). Elbow JT and CA also present a good reproducibility. Conclusion and perspectives: Preliminary results show that the use of both biomechanical and surface EMG measurements provide a wide range of reproducible indicators for a complete analysis of motor behavior during elbow F/E in healthy adults. The ongoing analysis of the database, comparing TD and CP participants, will attempt to provide indicators of abnormal muscle tone during voluntary movement, and a correlation analysis with spasticity assessed with the Modified Ashworth Scale by Bohannon et al (1987) will be performed. This could lead to a quantitative and user-independent method for the measurement of spasticity in CP children.

Poster #181

Effect of a three week tai chi intervention on dynamic postural stability in individuals with multiple sclerosis

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ABSTRACT

In Multiple Sclerosis (MS) the impairment of balance may lead to increased risk of falls and mobility loss. In quiet stance, MS patients display greater amounts of postural sway in internal perturbation tasks then healthy controls. Tai Chi is an ancient Chinese martial art that has decreased the risk of falling in frail elderly individuals (Wolf et al., 1996). The purpose of this study was to determine if a three week Tai Chi intervention would increase postural stability in individuals with mild to moderate MS. Seven participants (6F/1M, age 48.5 ± 10.8 years, height 1.66 ± 0.08m, mass 68.6 ± 19.8kg) attended nine one hour training sessions to practice two types of Tai Chi standing meditation. Postural stability was assessed before and after training using the center of pressure (COP) range, total excursion and velocity, and time to contact (TtC) in both anterior posterior (AP) and medial lateral (ML) directions. The postural tests consisted of quiet stance, Tai Chi standing meditation without Tai Chi arm movements, and Tai Chi standing meditation with arm movements. Participants were given 15 minutes practice time before performing the Tai Chi trials. Kinematic data were recorded by a 12 camera motion capture system (Qualysis AB), while the kinetic data collected from a single forceplate (AMTI) were used to compute net COP under both feet. Because functional parameters can influence stability, strength obtained from a chair raise test and neural drive obtained from a toe tapping test were assessed. All pre and post intervention results were compared using paired t - tests ($p<0.05$). Increases in muscular strength ($p=0.024$) and neural drive ($p=0.025$) were seen following the intervention. In quiet stance there were no differences between the pre and post test COP and TtC values ($p>.05$). For the standing meditation with arm movements, there was an increase in the COP velocity ($p=0.006$) and excursions ($p=0.023$) in the AP direction. There was also a reduction in both average TtC ($p=0.020$) and average minimum TtC ($p=0.012$) in the AP direction during standing meditation with arm movements after the intervention. The lack of difference from pre to post intervention quiet standing trials may have occurred because the activity of quiet stance itself may not have been challenging enough to cause changes in overall stability. As Tai Chi standing meditation with arms is a dynamic postural activity, the increased COP excursion and velocity and the decreased average TtC and average minimum TtC in the AP direction after the intervention, suggest that participants increased postural stability and confidence in establishing greater excursions that came closer to their limits of stability. The postural changes were accompanied by increases in muscular strength and neural drive. In Conclusion, the 3 week Tai Chi intervention program used in this study showed changes in dynamic postural stability, strength and neural drive in people with MS.

Poster #182

Efficiency of Klapp method to improve postural control in patients infected by HTLV-1: a baropodometric analysis

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ABSTRACT

One of the main goals of postural control in humans is to keep balance and stability using an appropriate base of support. Studies have demonstrated that patients infected with human T-cell lymphotropic virus type I (HTLV-1) have severe impairments hampering the maintenance of static balance (Poetker et al. 2011). The Klapp method was developed in 1940 by Rudolph Klapp and it consists of treating postural disability through the stimulation of proprioception in different challenging posture positions. The goal of this study was to determine the effect of Klapp method on the weight-bearing distributed by feet during upright position in patients infected by HTLV-1 associated with tropical spastic paraparesis. The participants were eight men with the diagnostic of HTLV-1 infection and with tropical spastic paraparesis, range of age from 25 to 35 years. The study follows a single subject experimental design type A-B, where A was measured at the baseline before intervention and B was measured five months after the intervention. The outcomes variables were the area of plantar pressure in the front foot (APP) and the center of pressure (CoP) during quiet stance. The outcomes were obtained with baropodometric using a barapodometer - Buratto Advance Technology Bioland Footwork ®. The means of trials for both outcomes were compared before and after treatment with a t test. This study was approved by the ethical committee of Universidade Federal de Sergipe (CEP - UFS). All subjects obtained significant changes after the treatment for both outcomes. Comparing the means of the eight subjects, for the APP they had before 58.2 ± 3.3 cm2 and after 43.5 ± 2.1cm2 ($p<0.01$). The CoP changed from 6.37 ± 2.46% before treatment to 9.46 ± 3.38% after treatment ($p<0.001$). The present study demonstrated that the Klapp method was efficient to decrease the weight support in the front foot and to increase the center of plantar pression in patients with tropical spastic paraparesis (HTLV-1). Therefore, our results suggest that the Klapp method can be used to improve postural control during static balance in patients infected with HTLV-1.

Poster #183

Postural stability analysis in teenagers with severe deafness and teenagers with artificially induced deafness

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ABSTRACT

Posture control involves the dynamic interaction of multiple systems. Congenital or early developed deafness is often associated with a delay or impairment in posture control. The goal of this study is to compare body sway during quiet stance in teenagers with severe deafness with age paired teenagers with artificially induced deafness. Forty nine teenagers were recruited and divided in three groups: Group A - 12 teenagers with deafness diagnostic since they were born, group B - 17 teenagers without hearing disorders who used a auricular protector during the experiment and group C - 20 teenagers without hearing disorders as a control group paired by age with group A and B. The outcomes variable were the center of pressure (CoP) during quiet stance recorded with baropodometric records using a barapodometer - Buratto Advance Technology Bioland Footwork ® and CoP displacement obtained with Save Center of Force software. This study was approved by the ethical committee of Universidade Federal de Sergipe (CEP - UFS). Results show differences between groups A&C (14,2±4,8 & 8,3±3,5 %, p<0,001) and B&C (12,3±3,5 &. 8,3±3,5 %, p<0,01). However, no difference was found between groups A&B (14,2 ± 4,8 & 12,3±3,5 %, p<0,382). The present study demonstrated that teenagers with congenital severe deafness and teenagers with artificially induced deafness have more body sway than their peers without any hearing disorders.

Poster #184

The Klapp method decreases body sway on standing balance in teenagers with idiopathic scoliosis

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ABSTRACT

Adolescent idiopathic scoliosis (AIS) is defined as a three dimensional deviation in the spine that can occur during puberty period. The AIS is more incident in girls than in boys. The symptoms of AIS include abnormal gait and balance. The Klapp method was developed in 1940 by Rudolph Klapp and it consists of treating postural disability through the stimulation of proprioception, joint mobilization and muscle strength in different challenging postures positions. The goal of this study is to compare body sway during quiet stance in teenagers with AIS submitted to Klapp therapy with age paired teenagers with AIS submitted to orthotic treatment with Milwaukee brace. The clinical study recruited 35 teenagers, female, with AIS Cobb angle ranged from 30° to 45°. They were allocated in two groups (20 girls on group A - Klapp method and 15 girls on group B - Milwaukee brace), paired by age (14,2±3,2 and 14,4±2,1 years), weight (56,2±2,5 and 61,3±3,6 Kg) and BMI (22,4±1,3 and 23,7±1,2 Kg/m2), respectively. Both groups started the treatment at the same time. The outcomes variable were the center of pressure (CoP) during quiet stance recorded with baropodometric records using a barapodometer - Buratto Advance Technology Bioland Footwork ® and CoP displacement obtained with Save Center of Force software. This study was approved by the ethical committee of Universidade Federal de Sergipe (CEP - UFS). The group A treated with the Klapp method obtained an improvement in body sway after the treatment and when compared with the group B treated with the Milwaukee brace it had a smaller CoP displacement, the size of CoP displacement for group A was 7,6±2,4 and group B was 18,0±1,6 % $p<0,001$). The present study demonstrated that the Klapp method was efficient to decrease body sway in teenagers with AIS, suggesting that the Klapp method can be used to improve postural control in this population.

Poster #186

The tonic stretch reflex threshold as a measure of ankle plantarflexor post-stroke spasticity: a reliability study

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ABSTRACT

One of the common impairments observed after neurological lesions is spasticity. Spasticity is defined as "a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes ("muscle tone") with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex as one component of the upper motor neuron syndrome". Persons with spasticity might experience difficulties in performing activities of daily living, and a reduction in their health-related quality of life. Using an appropriate clinical measurement for spasticity is of great importance to evaluate the effectiveness of therapeutic interventions. The most commonly used clinical tools to evaluate spasticity are the Ashworth Scales (original and modified). However, the validity and the reliability of these scales are questionable. The Montreal Spasticity Measure (MSM) is a promising objective alternative for the measurement of spasticity based on the calculation of the tonic stretch reflex threshold (TSRT). The TSRT corresponds to the joint angle at which the stretch reflex response begins. In healthy subjects, it is broadly regulated by descending and spinal pathways, as specified in the threshold position control theory. Limitations in the range of regulation of the TSRT in post-stroke subjects result in spasticity. Intra- and inter-evaluator reliability of TSRT estimation with MSM was previously demonstrated as moderately good for the measurement of elbow flexor spasticity in post-stroke participants. The purpose of the present study was to quantify the inter-evaluator reliability for the measurement of spasticity with TSRT estimation in another muscle group frequently affected by stroke-related spasticity, i.e. the ankle plantarflexors. Thirty individuals (9 females; mean age: 57.1 ± 9.8 yrs ranging from 40 to 72 yrs) with stroke-related spasticity at one or both ankles were recruited for this study. Plantarflexor spasticity in the most affected ankle was evaluated by two different evaluators. Each evaluator applied 20 manual stretches at different velocities. Soleus or gastrocnemius lateralis electromyographic signals, as well as ankle angular position were recorded with surface disposable electrodes and an electrogoniometer, respectively. For each stretch, velocity-dependent dynamic stretch reflex threshold (DSRT), which represents the joint angle at which the evaluated muscle begins to be recruited, was computed. The TSRT was then found by extrapolating a regression line through DSRTs to zero velocity. Inter-evaluator reliability was very good for the evaluation of spasticity in ankle plantarflexors, as shown by a two-way random Intraclass Correlation Coefficient of 0.821 ($p<0.0001$). The TSRT estimation is thus a reliable measure that might be a good alternative for the evaluation of spasticity in clinical settings and corresponds to a more physiologically feasible measure of disordered motor control post-stroke.

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Poster #188

The effectiveness of a reach-to-grasp task for motor learning in children with cerebral palsy

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ABSTRACT

Children with cerebral palsy (CP) have limited movements in upper limbs due to their limited range of motion, tone and sensation impairments, leading to functional problems. Learning new motors skills in adults can be related to sensory feedback. It is recognized that sensory deficits occurs in children with cerebral palsy which can impact movement production. Our aim was to determine if improved upper limb kinematics in children with cerebral palsy (CP) during a reach-to-grasp task could be retained and transferred to a similar task. We also characterized the relationship between sensation and motor learning. We used a prospective, single-subject research design with 16 children (7 males; 6-11 years old; spastic hemiparesis; Manual Ability Classification System, MACS 2-4). Children were randomly allocated to one of two groups: task-oriented training with or without trunk restraint. Children were paired by age and MACS scores. Intervention consisted of three 1-hr sessions per week for 5 weeks (total 15 hours). Interventions were performed in physical and virtual environment (order randomized). Evaluations consisted of sensory modalities (tactile threshold, touch, proprioception, stereognosis) and upper limb kinematics during reach-to-grasp of an object located near and far from the body (5 assessments: three pre-intervention, immediately post-intervention and 3 months post-intervention). Seven to 12 trials per target (close and far target) were recorded. The evaluators and subjects were blinded to group assignment. The upper limbs kinematics were recorded (Optotrak 3020, 100Hz; Northern Digital Waterloo) using 10 infrared-emitting diodes positioned at the arm and at the trunk. The kinematics measures consisted of the performance (Endpoint velocity, trajectory smoothness) and/or quality of movement (Elbow extension, shoulder flexion). To determine whether changes occurred for each kinematics parameters, linear regression was used and effect sizes was computed. No differences were found between groups in the number of children who retained or transfer their improvements in any of the four kinematics variables. Therefore, children in both groups were combined. Motor improvements could be retained 3 months after the intervention and transferred to a similar task in children with CP. Proprioception and tactile thresholds were associated with retention of improvements in endpoint velocity ($F_{2,13}=4.832$, $p=0.027$). Practice of activities aimed at improving upper limb kinematics led to better learning and retention of movement patterns for both performance and quality of movement in children with CP. Our results underline the importance of sensation for motor learning in children with CP.

Poster #196

Altered obstacle avoidance behaviour in individuals with good arm recovery after stroke

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ABSTRACT

After stroke, individuals with good sensorimotor recovery of their affected arm report decreased use of the arm in activities of daily living. Decreased use of the affected arm may be associated with undetected motor deficits which may be identified when individuals attempt higher-order tasks that require complex interjoint and intersegment coordination. One higher-order motor task, the ability to avoid obstacles while reaching, commonly occurs in everyday environments but is not routinely assessed by clinical scales. We hypothesized that well-recovered people after stroke would be less successful in avoiding an obstacle in the reaching path compared to age-equivalent healthy controls. Obstacle avoidance ability during reaching in a virtual environment (VE) was compared between well-recovered stroke subjects and healthy controls. A VE simulating a grocery store aisle and a commercial refrigerator stocked with bottles on 2 shelves having double sliding doors was developed. Subjects reached as fast as possible with their affected/dominant arm for a bottle on one shelf (non-obstructed reaching – template). In random trials (RAND, 30% of 60 trials), the door ipsilateral to the reaching arm closed and partially obstructed the bottle at reach initiation. Subjects were instructed to touch and retrieve the bottle without the hand or arm hitting the door. Arm and trunk movements were recorded with 24 active markers by an Optotrak system. Outcome variables were overall success rates, movement performance (endpoint tangential velocity, ETV; endpoint trajectory length, ETL) and movement quality variables (arm joint and trunk angles) for template (T), successful (Succ), and failed (Fail) trials, and Succ/Fail divergence points of the endpoint trajectory from template profile (DP=% of reach distance). Even in T trials, stroke subjects used less wrist flexion, wrist abduction and shoulder rotation compared to controls. In RAND, 36% of controls and 12% of stroke subjects were successful more than 65% of the time ($z=2.248$; $p<0.05$). For both groups, successful door avoidance was characterized by DP occurring closer to the starting position (control: $DP_{Succ}=11.2\pm7.0\%$, $DP_{Fail}=34.1\pm37.3\%$, $p<0.05$; stroke: $DP_{Succ}=20.5\pm16.1\%$, $DP_{Fail}=60.4\pm33.7\%$, $p<0.05$). However, stroke subjects had a smaller margin of error to avoid the door, as shown by DP and ETL values. DP_{Succ} occurred further from the start position in stroke compared to controls ($p<0.05$). In order to successfully avoid the door, both groups had to increase their ETL. However, since the ETL of stroke subjects was already longer than controls, increasing ETL did not result in successful door avoidance.Stroke subjects had residual movement deficits and made more errors compared to controls that were revealed through a challenging motor task. The potential of using challenging UL tasks to identify deficits in higher order motor control should be considered when assessing motor recovery after stroke.

Poster #197

Holistic Circus Therapy: Incorporating adaptive instruction and equipment

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ABSTRACT

Holistic Circus Therapy is a model of practice that uses circus skills to increase social, emotional, cognitive, and physical capacities of individuals and communities. The circus activities include; manipulation of different objects (hula hooping, juggling plate spinning), acro-balance, clowning and theatre games, balance based activities, and performance. Research completed in Australia in 2005 on education and circus activities resulted in the "Circus in Schools" evaluation tool demonstrating the positive impact circus has on the acquisition of life skills for youth in Australia. Two circus projects that took place in Cambodia in 2009, also demonstrated the effectiveness of circus on social and emotional health for marginalized youth as well as people with disabilities. Circus is currently being used as a treatment modality for adults with developmental disabilities in New Jersey, as well as elementary school and middle school children in the New York City school system to help individuals modulate sensory information, increase motor control capacities, and improve executive functions. The development of adaptive juggling equipment has enabled even more individuals with functional and learning differences to experience the motor control benefits that come from engaging in circus activities. Combining circus activities with evidenced based practices currently used within occupational therapy has demonstrated increases in coordination, body awareness, team work, problem solving, perseverance, fitness, strength, and the acquisition of life skills for various populations.

POSTER SESSION III (continued):

Theme VI: Motor Control and the Performing Arts

Poster #14

Gray matter differences in professional dancers

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ABSTRACT

Studying individuals with specialized training, such as music and dance, offers a unique window to study brain plasticity. While several studies have investigated the neural correlates of music training (Wan & Schlaug 2010), only one study has examined structural brain differences between dancers and non-dancers (Hänggi et al., 2010). The goal of the present study was to identify the effects of long-term dance training on the brain, specifically in terms of gray matter thickness. Participants included 15 professional adult dancers and 15 age-matched controls. Dancers were recruited from professional dance schools and had 10 or more years of dance training, but no formal music training. Controls had no formal experience in dance, music, figure skating, aerobics or any competitive sport. T1-weighted MR sequences were obtained for all subjects on a 3 Tesla Siemens scanner. Statistical analyses were performed at every point on the cortical mantle to test for region specific group differences in cortical thickness. Age and gender were included as covariates. Results were thresholded over the whole brain at $p<0.001$ uncorrected. Preliminary analyses revealed that dancers had thicker cortex in bilateral medial superior frontal gyri, middle frontal gyri, dorsolateral frontal gyrus, and the anterior cingulate relative to controls (Figure 1). These findings are consistent with previous results of gray matter differences in frontal cortex of dancers (Hänggi et al., 2010). Our next step is to correlate brain structural differences in dancers with their behavioral performance on a battery of auditory, visual and motor tasks. This research will advance our knowledge on brain plasticity in relation to behavior, and may have applications for future therapies in motor disorders.

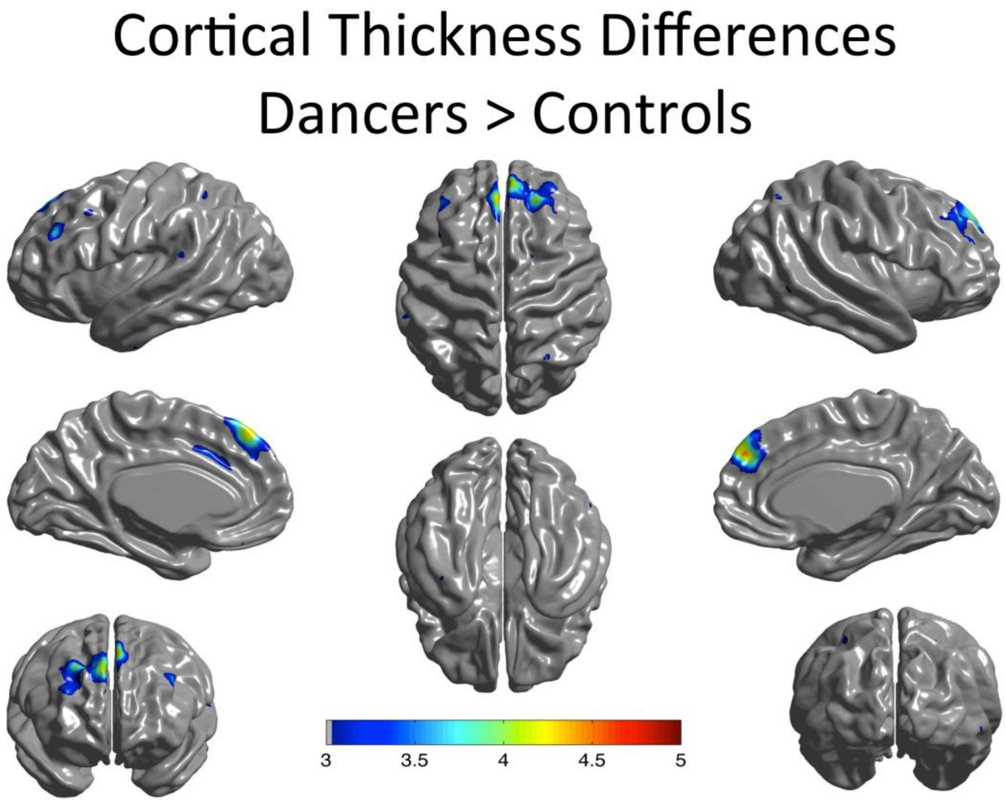

Figure 1. Preliminary analyses revealed that dancers had thicker cortex in bilateral medial superior frontal gyri, middle frontal gyri, dorsolateral frontal gyrus, and the anterior cingulate relative to controls.

Poster #33

White-matter differences in professional dancers

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ABSTRACT

Both music and dance involve long-term training of sensory and motor skills. Several studies have investigated the brain underpinnings of musical training (Wan & Schlaug 2010), but only one study has examined the structural neural correlates of dance (Hänggi et al., 2010). The objective of the current study was to examine white matter integrity in dancers versus controls. Participants included 15 professional adult dancers and 15 age-matched controls. Dancers were recruited from professional dance schools and had 10 or more years of dance training, but no formal music training. Controls had no formal experience in dance, music, figure skating, aerobics or any competitive sport. Diffusion-weighted images were acquired for all subjects on a MR 3T Siemens scanner. To measure white matter integrity, we calculated: Fractional Anisotropy (FA), Mean Diffusivity (MD), Axial Diffusivity (AD) and Radial Diffusivity (RD). Statistical analyses were performed using FSL software (Smith et al., 2004) and thresholded over the whole-brain at $p<0.05$ corrected for multiple comparisons. Preliminary analyses revealed that dancers had lower FA and higher RD in the right hemisphere, involving the superior longitudinal fasciculus, the cortico-spinal tract and the superior corona radiata. These findings are consistent with some previous results of reduced FA in fronto-parietal areas of ballet dancers (Hänggi et al., 2010). Our next step is to correlate brain structural differences in dancers with their behavioral performance on a battery of auditory, visual and motor tasks. This work serves to better understand brain plasticity in relation to behavior, and may guide future interventions in motor disorders.

Poster #35

Sensorimotor adaptation to a gesture-sound mapping perturbation

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ABSTRACT

There is a growing interest in performing arts to use tangible interfaces and motion sensing technology to control digital sound with gestures. Nevertheless, the evaluation of sensorimotor learning is very rarely addressed in this research domain. We initiated a series of experiments (ANR LEGOS project) to study sensorimotor learning in motion-based interactive sonic systems. We designed an experimental study focused on sound feedback inspired by experiments on motor adaptation with visual feedback. The system is based on specific sound controller consisting in a small handheld object which motion drives a synthesizer (using physical modeling). In particular, the angular velocity is captured in real-time by a gyroscope and transmitted wirelessly to the sound engine simulating a string bowing. The task is to reproduce a targeted sound, corresponding to a targeted velocity profile. If the velocity profile is accurately performed, a clean sound is heard, while incorrect velocity profile either produces noisy or detuned sound (depending on higher or lower velocity values). The experiment consisted in two phases. In a first phase, 14 adults learned the system with an optimal velocity profile A. In a second phase, the same participants were then blindfolded and were asked to produce again the target sound, but with two other profiles B and C following a B-C-B sequence). The results showed that generally participants were able to learn to control the target sound: significant learning processes were noticed during the first phase (12 participants showed significant improvements with repetition). The second phase showed that motor adaptation was occurring, and was dependent on the type of profile alterations (10 and 7 participants showed significant adaptation for B-C and C-B transitions, respectively). In conclusion, these studies showed that more than 50% of the participants exhibited sensorimotor adaptation in this audio-only task.

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Poster #36

The effects of dance classes in the motor control of stroke patients in Southern Brazil

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ABSTRACT

This text presents considerations resulting from a research on the effects of dance lessons in the motor control of stroke patients in Porto Alegre, Rio Grande do Sul, Southern Brazil. This study is being developed since 2011 at the dance undergraduate course in the Superior School of Physical Education at the Federal University of Rio Grande do Sul (ESEF/UFRGS) and is the continuation of previous smaller editions in Baltimore (USA) in 2009 and Zürich (Switzerland) in 2010. The goal of this study was to verify whether dance could contribute to the motor control of the stroke patients. Seven chronic stroke patients participated in the research and took dance classes once a week for 1 hour for a period of four months. The activities were planned taking a Somatic approach as starting point which directs practices from a series of different dance techniques and forms, aiming at an optimization of motor learning and control of the participants. Data collection was divided into 2 stages: the first was done before the beginning of the training period; and, the second at the end of it. Data collection instruments included the *Timed Up And Go Test* and *Berg Balance Scale*. Data collected through the Berg Balance scale and *The Timed up and go Test* were analyzed and demonstrate improvements in the balance of the participants as well as in gait mobility and in most of the analyzed movements such as pivot, weight bearing and transference, changes of direction in space, movements in different rhythms, leg movement precision. So far, the results offer a series of reflections that point to the planning of educational strategies and activities in dance that allow for the inclusion of people with special needs and the improvement of their motor abilities.

Poster #38

Intentional switching dynamics in Japanese martial arts

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ABSTRACT

Nonlinear dynamics has revealed that complex phenomena, from chemical reactions to the neural networks in the brain, emerge from simple principles. Examples of complexity theory include self-organisation in thermodynamics theory, the slaving-principle in lasers, spatiotemporal chaos in fluid dynamics, and the synchronisation of nonlinear-coupled oscillators. Humans are considered to be complex systems as well. In response to various situations, people make instantaneous decisions and execute appropriate motor behaviours. Typical examples of this include the processes involved in interpersonal competition, such as fencing or Japanese martial arts originating from Samurai traditions. Decision making, which depends on prefrontal cortical activity, has been modelled based on neuropercolation, which is a generalisation of cellular automata, for stochastic and/or symbolic dynamics. In contrast, self-organisation phenomena in human motor coordination have been studied as entrainment of nonlinear coupled oscillators and this has been extended to interpersonal coordination. However, the dynamics underlying the continuous and abrupt switching of human behaviour, such as that exhibited in martial arts, remain unclear. Here, we report that intentional switching dynamics, associated with continuous movement during interpersonal competition, emerges from simple syntax. We observed a time series of interpersonal distance between two players during 24 kendo matches. The subjects included 12 experts and 12 intermediate-level players. A return map analysis was applied to 346 scenes during the matches, and function fitting using three to six points was performed for each scene. The results revealed six functions including linear functions with four different slopes: two attractors and two repellers, an exponential function, and a logarithmic function of intermittency. We found that 290 (79.7%) of all scenes could be fitted by the candidate functions. Moreover, we found 121 scenes were switched among two-to-four different functions in each scene. State transition analysis revealed that skill differences were evident in the second- and third-order state transition diagrams for these two attractors. Our results suggested that abrupt switching between attractors is related to the diverse continuous movements resulting from quick responses to sudden changes in the environment. This abrupt switching-quick response behaviour was characterised by joint action syntax. The resulting hybrid dynamical system is composed of a higher module with discrete dynamics and a lower module with continuous dynamics. Our results suggest that human intelligent behaviour and robust autonomy in real-life scenarios are based on this hybrid dynamical system, filling a gap between interpersonal coordination and competition.

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Theme VI: Motor Control and the Performing Arts

Poster #40

Separating perception and production abilities in auditory-motor processing of musician's dystonia patients

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ABSTRACT

Musician's hand dystonia (MD), a form of focal dystonia, is a movement disorder that is characterized by a loss of voluntary motor control of skilled hand movements during instrumental playing. The pathophysiology of this movement disorder is still unclear but research indicates that in addition to altered inhibition patterns at different levels of the central nervous system, also maladaptive plasticity -e.g. in the basal ganglia and in the sensorimotor cortices-, and alterations in sensorimotor integration might contribute to the disorder. Furthermore, several studies showed that not only the control of the movements necessary to successfully play their instrument is affected in MD patients but also that their timing and discrimination abilities are impaired. Our aim was to investigate at what stage of auditory-motor processing deficits occur by employing a variety of auditory-motor tasks. Furthermore we explored the relations between the five tasks. Sensorimotor synchronization (SMS) is the temporal coordination of an action with events in a predictable external rhythm. SMS is a fundamental human skill that contributes to successful motor control in daily life and plays an important role during -ensemble- music making. Participants synchronized their tapping with tempo changing and adaptive auditory sequences, to address anticipation and adaptation abilities. An adjusted version of the Beat Alignment Test (BAT) was used to examine precision of beat synchrony perception. Performance on these tasks was compared with elementary perceptual tasks, namely anisochrony detection and auditory-motor delay detection. Taken together, the tasks aim to separate the purely perceptual capacity from production abilities that are important for SMS and therefore provide a picture of the timing abilities of MD patients.

Poster #45

Interpersonal distance emerges as a "not-to-lose" strategy in a play-tag sport game

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ABSTRACT

Patterns of interpersonal motor coordination can widely vary according to purpose of the interacting performers. In this study we designed a prototype sport task to investigate the behavioral coordination that emerges in interpersonal competitive situations. We asked 5 pairs of naive participants to engage in a play-tag game in which they had to remove a tag fastened to their partner's hip. Participants' 3D movement trajectories during trials were recorded (at 100Hz) using optical motion capture system with four cameras. Relative phase analysis of the players' step towards-away velocities (for detail, see Kijima, A. et al., PLoS One, 7(11), e47911. doi: 10.1371/journal.pone.0047911.) indicated that dynamically stable anti-phase synchronization evolved across 10 repetitions of the game, that includes active predator-prey role transitions. Importantly, this tit-for-tat anti-phase synchronization was especially frequent when the interpersonal distance between the players becomes into 0.4-0.6 m in initial trials of repetitions. However in later trials (c.f. later than 8th trials), this distance in which anti-phase dominated was extended to 0.4-0.8m range. Thus, the findings of the current experiment can be concluded into following two points: 1) Players' movement coordination patterns converged to anti-phase synchronization in 10 times repetition of the game, 2) pairs of synchronizing players maintained certain distance already in initial trials of repetition, and this distance increased with trial repetition. We evaluate the evolution of this synchronization process dynamical model with an attractor at relative phase of 180 degrees and a repeller at 0 relative phase as well as discuss the self-organized nature of model and its ability to embody a general solution for interpersonal coordination in martial arts.

Poster #48

Neuropsychological characteristics among dystonic musicians: A comparative investigation into neuropsychological trigger factors and treatment effects between musicians and athletes

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ABSTRACT

Musician's focal dystonia (MD) is a task-specific movement disorder affecting instrumental performers. It is characterized by task-specific, mainly painless, involuntary muscle contractions, which lead to abnormal postures (cramps) and loss of movement coordination. The aim of the project is the identification of neuropsychological trigger factors in dystonic musicians and the comparison with athletes suffering from the yips, a similar movement disorder in golfers. Twenty-four musicians with dystonia and twenty-four control musicians participated. All subjects filled in three psycho-diagnostic standardized questionnaires (WAI-T, MPSF, SVF78) in order that their psychological profiles could be explored. A cluster analysis (hierarchical and a K-mean classification) indicated two distinct heuristic models (one per group), which underline psychological differences between groups and among participants within groups. Results revealed that dystonic musicians could be subdivided into two subgroups with: 1) the majority of patients who show high perfectionistic standards and cannot deal sufficiently well with stress and 2) those patients who developed dystonia in the absence of perfectionism and stress. The development of the dystonia in the latter subgroup could largely be explained by extrinsic triggering factors, such as temporal and spatial constraints (instruments requiring maximal fine-motor skills, extensive practicing etc.). The heuristic model of healthy musicians revealed no consistent neuropsychological profile. The resulting categorization of dystonic patients can facilitate the diagnosis of future cases. Besides neurological treatments, other neuropsychological support (e.g. psychotherapy) may be needed. The next phase of the current study will focus on various physiological and phenomenological differences between the detected subgroups.

Theme VI: Motor Control and the Performing Arts

Poster #49

The relationship between age of onset of musical training and finger tapping performance

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ABSTRACT

Previous research from our laboratory suggests that adult musicians who began their musical training before the age of 7 years (early-trained musicians, ET) perform better on auditory-motor synchronization tasks compared to musicians who began their training after 7 years of age (late-trained musicians, LT). Brain differences between these 2 groups have also been found using structural magnetic resonance imaging (MRI) and diffusion tensor imaging. These results hold even when ET and LT groups are matched for total years of musical training. The present study investigates the effects of musical training on the task of finger-tapping to a metronome and will examine structural brain differences in regions associated with the timing process that is thought to be used in this kind of repetitive movement task. As part of a larger study that examined ET-LT differences, we tested 12 non-musicians, 16 LT musicians (mean age at start of musical training = 11.13 years), and 11 ET musicians (M = 4.82 years old). Each participant finger tapped to a metronome (the Paced phase) and then maintained the target tapping rate as best they could once the metronome had stopped (the Continuation phase). This was done at each of 3 different rates (every 250 ms, 500 ms, and 750 ms). Finger movement was recorded with a motion capture system and structural MR brain images were obtained separately. Initial analysis of the Continuation phase using the Wing-Kristofferson (1973) model of inter-response interval variability indicates no differences between the ET and LT groups. Additional analyses to be carried out include an examination of kinematic parameters such as movement jerk and velocity and acceleration profiles. We will also examine volumetric differences in cerebellar regions as well as the relationship between MRI cerebellar volumes and task performance. The results of this study will add to our understanding of a sensitive period for musical training in early childhood.

Poster #54

The effect of precision requirements in violin bowing tasks on torque loading of the bowing arm: an inverse dynamic analysis

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ABSTRACT

Upper extremity musculoskeletal disorders (UEMSD) are common among stringed instrument players. It is possible that such disorders are related to the famously high precision demands of musicianship. Indeed, it has been speculated that tasks featuring high precision requirements (HPR) pose an increased risk of developing UEMSD in many worker populations. According to a prevalent hypothesis (e.g. Srinivasan et al., 2012), HPR impose restrictions on variability of motor execution in task performance. In turn, such motor stereotypy leads to relatively invariant (stereotypical) patterns of loading of articular and/or musculotendinous limb structures, thus selectively exposing them to undue cumulative stress. However, it remains unknown whether HPR are indeed associated with decreased variability of multiarticular limb trajectories in highly skilled performers. It is equally plausible that, rather than suppressing motor variability globally, elite performers respond to HPR by favoring task-irrelevant patterns of joint motion variability, thereby reducing the stereotypy of joint-space trajectories. In such a scenario, the performer's adaptive response may be self-protective rather than injurious. In our presentation, we will describe preliminary results from a study of elite violinists, who are asked to perform a bowing task in which the level of required precision is systematically manipulated. Data obtained via 3D motion capture and a force-sensor-augmented bow (Young, 2007) will be used to transform reaction forces from the bow-string interface to the joint moments of the player's upper limb. Through such inverse dynamic analysis, we will determine the effect of HPR on patterns of joint torque variability. In addition to informing an etiological model of musicians' UEMSD, our work will enhance understanding of how expert performing artists respond to the exacting psychophysical demands of their work.

Poster #66

Auditory-motor interaction in violin bowing: Timing, coordination and pattern formation

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ABSTRACT

In violin performance the primary function of bowing movements is to exert instantaneous control of the sound. In addition, bowing movements have to be planned ahead in order to anticipate future events. Already in simple note sequences this leads to complex movement patterns, in which sound control, timing and anticipation are integrated. An interesting class of bowing movements are repetitive bowing patterns involving bow changes and string crossings. At fast tempo the movements form fluent two-dimensional patterns, typically circular or figure-of-eight shaped. The coordination (or relative timing) of string crossings and bow changes, which is critical for a good performance, is inherent in the shape of the motion pattern. The aim of the current study is to shed light on coordination and the role of auditory-motor interaction in the formation of bowing patterns. A motion capture study was conducted with 22 violinists (8 amateurs, 8 students and 6 professionals), who were asked to perform repetitive bowing patterns at different tempi and dynamic levels. It was shown that string crossings were consistently timed earlier than bow changes in the performance of all players, which was achieved by a small phase difference of about 10-30 degrees between the two orthogonal quasi-sinusoidal movement components. Interestingly, there were no obvious group differences in the average and variance of the coordination patterns, indicating that this behavior represents a relatively basic performance skill. In addition, a perceptual experiment was conducted using simulated control gestures on a virtual violin. The coordination of bow changes and string crossings was set by participants by adjusting a slider. This led to similar coordination patterns, suggesting that the observed motor behavior in performance reflects an optimization of the acoustic quality of note transitions.

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Poster #91

Movement timing determines perceived auditory timing in a sensorimotor integration task

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ABSTRACT

Moving (tapping) to the beat can objectively improve the perception of timing, with less variable movement presumably leading to better perceptual timekeeping abilities, supporting evidence for crosstalk between auditory and motor systems (Manning & Schutz, in press). Here we examine this assumption in the context of a task we designed to explore the effect of movement in timing perception. In this experiment participants heard a series of isochronous beats, and were asked to identify whether the final tone after a short silence was consistent with the timing of the preceding sequence. On half of the trials, participants tapped along on an electronic drum pad up to and including the final tone, and on half of the trials they listened without tapping. We recorded the tapping and analyzed the timing of each final tap. For the tapping trials we compared the proximity of the final tap to the expected position of the final tone and to the actual position of the final tone on each trial. When the final tap was closer to the expected position of the final tone, participants were better at identifying the timing of the last beat. Additionally, when participants tapped closer to an incorrectly timed final tone, they were more likely to incorrectly estimate the position of the final tone. While previously we demonstrated an effect of movement on perceived timing, here, by analyzing tapping information, we observe a clear dependence on correctly timed movements for judgments of auditory timing. These findings provide evidence that despite the auditory system's capacity for precise processing of temporal information, we can use movement information to make judgments about the timing of auditory events.

Poster #94

Postural sway in performing vocal duets: Effects of visual and acoustic cues

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ABSTRACT

Postural control is important for singing, and is constrained by the demands of breath support. Postural sway, however, is less constrained. Singers often sway while standing for long periods during performances typical of vocal ensembles, and they can use body motion to signal upcoming acoustic changes to their ensemble partners. Perception-action coupling in ensemble music performance is also influenced by the acoustic relationships between the musical parts produced by different ensemble performers. We examine the postural sway of skilled singers who stood on force plates as they performed simple melodies in Solo (individuals performing the same melodic content alone), Unison (duet partners performing the same melodic content simultaneously), and Round conditions (duet partners performing the same melodic content with one duettist's part temporally offset from the other). Influence of visual feedback about the partner's movement was manipulated by facing the singers Inward (full view of each other) and Outward (no view of each other), while normal acoustic feedback was maintained across all conditions. Vertical Ground Reaction Forces (GRF) and anterior/posterior and medial/lateral Center-of-Pressure (CoP) measures each indicated greater variability during Round singing than during Unison or Solo singing. Correlations on vertical GRF measures indicated increased correspondence in posture between duet singers in Unison than in Round conditions. Inward/Outward facing had less influence on force correspondence measures across conditions. These findings suggest that changes in posture by standing vocalists are influenced more by acoustic cues than by visual cues from their partners.

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Poster #115

The Magic of Movement: Integrating magic into rehabilitation for children with hemiplegia

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ABSTRACT

Children with movement disorders such as cerebral palsy (CP) have been shown to have a broad range of difficulties including poor visual spatial skills and executive control and are at a significantly higher risk of concomitant psychiatric disorder. Intensive therapy programmes are difficult to implement and may suffer poor adherence/compliance. Interventions need to be creative to cover these broad areas of deficit and engage children in the therapy process. The objective of this study was to report on the use of 'Magic' as both a performing art and intensive motor therapy (prestidigitation) for children with hemiplegia (CH). Forty-three children with hemiplegia (24 males,19 females; mean age 10y7mo, range 7y-16y) have participated in two week intensive summer camps which embedded magic hand tricks into the therapeutic protocol of the Hand Arm Bimanual Intensive Therapy approach. Additionally, children participated in costume and theatre design work to put on a magic show at the end of the 2-week summer camp. Primary outcomes involved extensive motor evaluation including: Assisting-Hand-Assessment (AHA), Jebsen Taylor Test of Hand Function (JTTHF) and Children's Hand Experience Questionnaire (CHEQ). Secondary outcomes explored impact on psychosocial aspects including resilience via the Hope Scale and interviews. Changes in motor skill were evident across measures: Bimanual use on the Assisted Hand Assessment (AHA; ($F(2,21)$ =9.83, p=0.001, η^2 =0.48; mean difference: pre-to post-camp=5.93, CI: -9.52 to -2.34, p =0.005); Independence in daily activities on the CHEQ Assessment ($F(2,25)$=20.13, $p < 0.001$,η^2 =0.53). with results maintained at 3-month follow-up (mean difference: pre-to post-camp=22.18, CI: -38.79 to -5.57, $p < 0.001$; pre-to follow-up=15.66, CI: -31.04 to -0.29, p=0.001); and Speed of performance in unimanual skills on the JTTHF (total time $F(2,38)$=17.04, $p < 0.001$, η^2 =0.40, All children made gains of at least one 'least degree of difference' (LDD: representing clinically meaningful change (LDD=1.96 * sqrt2 * SEM) or 20% progress on at least one of the primary outcome measures, Psycho-social outcomes show gains in positiveness and hopefulness (HOPE scale t (17) -2.05, p=0.05) with significant positive comments from parents on reflecting empowerment and improved confidence. These results reflect positive motor and psychosocial benefits from incorporating Magic into therapeutic protocols for children and provide exciting opportunities for further research and development.

Poster #119

Synchronizing tapping with the beat of complex auditory sequences

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ABSTRACT

Humans often tap along with the perceived 'beat' of rhythmic auditory sequences, such as music. The beat is a periodic, perceived emphasis that accompanies metrically structured auditory rhythms. Beat-synchronized movements depend on the accurate anticipation of the beat, however the persistence of and limits to beat perception are not fully understood. Here, we investigated beat-synchronized tapping to auditory tone sequences that have different amounts of conflicting rhythmic information. Each trial consisted of 2 overlaid metrical, rhythmic sequences. In each trial, one rhythm began, inducing beat perception, and the second rhythm faded in after about 7 seconds. The tones in all rhythms were sine tones of the same frequency, effectively creating a single, complex rhythmic sequence while two rhythms were being presented simultaneously. After about 13 seconds of simultaneous presentation, the first rhythm was stopped, leaving only the second. Participants tapped in synchrony to the first rhythmic sequence and continued through the entire trial. We measured how introduction of the second rhythm disrupted synchrony. The pairs of rhythmic sequences in individual trials were either tempo congruent (TC) or incongruent (TI) (having the same minimum time-interval between tones, or not), and either metrically congruent (MC) or incongruent (MI) (having the same beat-structure, or not). This provided 4 conditions of trials: TCMC, TCMI, TIMC, and TIMI. In all TI trials, the metrical structure of the perceived rhythm was violated, therefore expected participants' tapping to be more variable in TI than TC trials. In all TC trials, a plausible metrical structure remained, but only weakly when the two constituent sequences were metrically incongruent, so we expected tapping for TCMI trials to be more variable than for TCMC trials. Preliminary analysis of tapping data confirms our first hypothesis. Tapping variability was greater for TI trials compared to TC, and for TCMI trials compared to TCMC. Difficulty ratings mirrored these effects. These results suggest that it is difficult, yet possible, to maintain beat-synchronized tapping to a metrically structured auditory rhythm, even when a metrically conflicting rhythm is introduced, rendering the resulting rhythmic sequence metrically implausible.

Poster #142

Comparison between visual, auditory and visuoauditory cueing on timing of movement

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ABSTRACT

Cueing can be used to train a new motor task. Visual, auditory and visuoauditory cueing has been explored to improve motor ability in normal as well as various neurological disorders. Responding in a more accurate and appropriate time signifies the success of cueing. Hence we aimed to identify the best cueing method in-terms of timing for training upper limb task. Thirty normal healthy volunteers participated in the study. All of them were non-musicians. A four key basic rhythm was recorded using Acoustica Mixcraft 5.2. Prior to the study a random auditory stimuli was given to the subjects and their response time was recorded. Later the experimental sound was played to the participants to make the music familiar to them. The keys were also shown to the subjects. The subjects were then asked to play the music in three cueing conditions. One with auditory cueing where the music was played in the headphone, one with a visual cue where a visual display the key timing was shown and in the third both the cues where given together. The sequence of cueing was randomized and the difference between the target time and the actual time was taken for analysis. The mean response time was 329.85± 26.2. The difference between the four target time and the actual time for auditory cueing ranged between 120.75 msecs to 285.05 msecs, for visual cueing was between -186. 45 to -68.65 m sec and for visuoauditory cueing the response time ranged between -52.00 to 43.95 msecs. The results suggest that auditory cueing has a delay in the time and the visual cueing always produced response ahead of time. Visuoauditory cueing produced the best responses for timing accuracy.

Poster #146

Motor learning of classical ballet with feedback of reduced dimension in children with cerebral palsy

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ABSTRACT

Cerebral palsy (CP) is the most common cause of developmental physical disability in childhood. It is characterized by abnormal muscle tone and reduced selective motor control. These deficits compromise functional mobility, thus therapy is essential for children with CP. We have shown that the use of feedback of reduced dimension in a virtual reality (VR) environment using classical ballet movement tasks enhances clinical measures of balance, dissociation of movements, and grasps in children with CP. The goal of this investigation was to examine motor learning in children with CP based on low-dimension remapping of classical ballet postures performed of by age-matched typically developing (TD) children using a VR environment. The group of TD children performed a sequence of ballet postures requiring selective shoulder joint control in task 1 and additional hip joint control in task 2. Each child wore 8 reflective trackables recorded by the NaturalPoint® OptiTrak at 100Hz with 8 cameras. The resulting 24-dimensional space was then reduced to a 2-dimensional space for VR feedback display using principal component analysis. A group of children with spastic CP (n=10) and dystonic CP (n=4) ages 8-12 and Gross Motor Function Classification Score I-II trained with this program for a total of 6 sessions over 2 weeks with kinematic tracking of their motions. After testing, the children with both spastic and dystonic CP demonstrated motor learning by increasing the total number of matches with the target postures from the first to the last training session in both tasks. Two-tailed t-tests showed a significant increase in the number of exact matches (alpha=0.05) for the spastic group (p=0.0019) and the dystonic group (p=0.0433) in task 1. Additionally the children with spastic CP had a significant increase already evident by training session 5 (p=0.0142). In task 2, significant improvement was only seen in the spastic group (p=0.0015). Analysis of the trajectory smoothness was computed using the spectral arc length metric based upon the Fourier magnitude spectrum of the movement speed. In Task 1, the group of children with spastic CP demonstrated significantly increased (alpha=0.05) smoothness of trajectory in 7 of the 8 trackables and in task 2 they demonstrated significant improvement in one trackable representing the right hand. The group of children with dystonic CP demonstrated no significant improvement in either task. Additionally, they actually had less trajectory smoothness by the last training session in task 2. This presentation discusses the quantitative evaluation of classical ballet technique as a possible component of rehabilitation therapy and addresses possible quantitative markers to differentiate spasticity and dystonia in CP so as to optimize their clinical classification and therapeutic interventions.

Poster #147

Auditory motor integration in cello players

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ABSTRACT

Auditory motor integration is a skill fundamental to activities such as speaking, singing, and playing a musical instrument. However, it is unknown what neural circuit governs this expertise. Zarate and Zatorre (2005, 2008) have addressed this issue using the voice as a model instrument. Voices, as well as non-fretted string instruments such as the cello, have a continuous pitch mapping. This means that, once a note has been produced, the pitch must be altered based on real-time auditory feedback. However, the voice relies on the muscles of the vocal apparatus. This system is evolutionarily old, and is used for speech and non-speech vocalizations as well as for singing. The auditory-motor mapping of the cello, on the other hand, is arbitrary and learned explicitly. For this reason we propose that studying cello players will provide novel information regarding auditory-motor control, which is complementary to that of the vocal literature. This study aims to characterize expert cello players' motor response to pitch altered auditory feedback, and the neural correlates thereof. For this experiment, cello players were asked to listen to and, subsequently, produce a series of single notes on an electric cello. Auditory feedback was delivered to participants via headphones such that the experimenter could alter its pitch. Participants were asked to compensate for the pitch perturbations immediately. Their auditory output was recorded directly from the cello. These methods were designed such that they closely parallel those of Zarate and Zatorre (2005, 2008). The data from the behavioural task is currently being analyzed in order to determine the degree to which participants compensated for the pitch perturbations. We anticipate that they will show total compensation, as was the case in trained vocalists. An MRI compatible cello has been designed for use in the fMRI neuroimaging study, which will follow the behavioural investigation.